Functional Animation

Interactive Animation in Digital Artifacts

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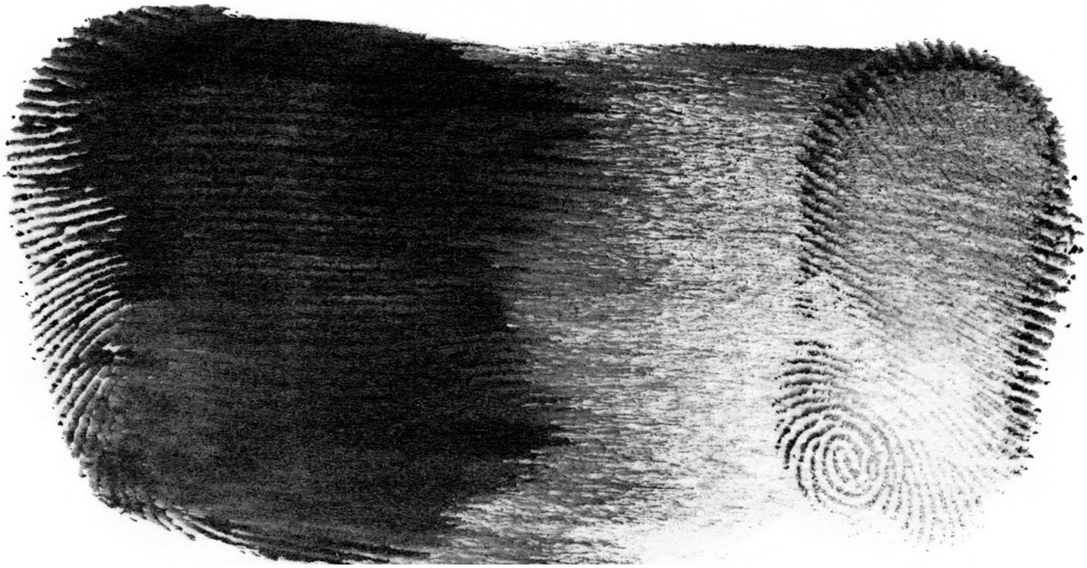

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INTERACTIVE ANIMATION IN DIGITAL ARTIFACTS

BY
MORTEN LUND

DISSERTATION SUBMITTED 2016

AALBORG UNIVERSITY
DENMARK

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Animation [an-*uh*-**mey**-sh*uh* n]
from latin
animātiō: a bestowing of *life*
animātus: filled with breath or air, quickened
anima: breath, vital force, soul, spirit

Motion should first and foremost be practical. It should orient users with clarity and conviction. It must fundamentally improve, not merely embellish, our experience and interactions. Motion doesn't just animate things. It guides people, with intention and precision, through the complex spaces of the UI.

Microsoft Design Language Styleguide, March 2016

CV

Morten Lund
Born 1970

Degree in Human Computer Science from Aalborg University, 1997. Interaction designer, Design lead and Product manager in the mobile industry between 1999 and 2008: Bosch Telecom, Siemens Telecom, TTPCom UK and Motorola. Developed full reference UI for 2nd generation handset and accompanying documentation standard and system. Freelance Interaction designer during 2009.

External lecturer at Aalborg university since 2004. Three months employment at Bang & Olufsen to develop and implement documentation strategy during 2011 after commencement of Ph.D.-project in january 2010.

Member of steering committee of NIBF (regional professional network, closed) and Sigchi.dk[1] until 2015 (national professional network, not associated to ACM).

[1] renamed to uxdanmark.dk in 2015

SUMMARY

This dissertation concern the use of movement as a component in the design of interactive digital systems. The research establish how movement as an independent meaningful phenomenon contribute to the usefulness, aesthetic experience and interactivity of interactive digital systems. *Animation* is the practical and scholarly discipline that concern the creative control and manipulation of movement. *Interaction design* is the practical and scholarly discipline that concern the design of human relation to interactive digital systems. A literature review establish that neither Animation nor Interaction design has a particular concept for movement in the context of interactive digital systems. The term *functional animation* is proposed as conceptual frame for the overlapping area between Animation and Interaction design. Eight research activites are performed to establish functional animation as an independent area of research and practice that inform and is informed by both Animation and Interaction design.

A historical account of the integration of movement in Interaction design illustrate how movement has been part of interaction design since Donald Sutherland's Sketchpad system and that animation was first conciously integrated into interaction design activities by Alan Kay via Ronald Baecker and animator Eric Martin for the development of the Xerox PARC Smalltalk system in 1973. Movement has been an integrated part of the WIMP GUI paradigm since conception. The historic account also demonstrate how the use of animation within the practical setting of a tool is a novel use of animation expressiveness. Animation studies is researched to position functional animation in relation to other uses of animation. This leads to a model of animation usages that allow mapping in relation to animation type (T) and purpose (P), and field (F) and discipline (D). This TPFD-model includes a distinction between linear and interactive animation. An investigation into the definition of animation leads to a definition of interactive animation and the specific use represented by functional animation: *Functional animation is the control in creation, production, execution, and consumption of motion, as an expressive component, to convey meaning, in a visual, interactive, user interface environment.*. The rationales for viewing '*the illusion of life'* as the essence of animation are established. These invetigations into animation and the presence of functional animation as a particular use of animation are supplemented by the proposal of a set of principles for the design of functional animation that position the communicative purposes as subordiante to existing principles of Interaction design: *Transition, Transformation, Progress, Acknowledgement, Hint, Attention* and *Illustration*. This is followed by the proposal of a framework for practical application of these principles in relation to development of concrete motion patterns that build on the relational *'action – re-action'* character of functional animation.

The theoretical research activites are supported by an empirical study that explores the meaning of motion as an independent phenomenon within an interactive digital

system. The study collects quantitative responses from 188 people on their experience of difference among five visually identical, but motionally different objects. The study is performed via an Apple iPad app that integrates the survey and the practical exercise. The study show that people are capable of discerning among the objects based only on their motional difference and thus that movement as the primary associative stimulant is meaningful. The study also show that respondents are not in agreement when evaluating the difference in terms of material and character. The abstract de-contextualised environment represented by the study exercise offer no references to known contexts and thus the study show the importance and influence of context when performing tests. The study therefore establish an empirical foundation for exisiting and future contextual studies of functional animation.

DANSK RESUMÉ

Denne afhandling angår anvendelse af bevægelse som en komponent i design af interaktive digitale systemer. Forskningen angår, hvordan bevægelse som et selvstændigt meningsfyldt fænomen bidrager til brugen, den æstetisk oplevelse og interaktiviteten i interaktive digitale systemer. Animation er den praktiske og videnskabelig disciplin, der vedrører kreativ kontrol og manipulation af bevægelse. Interaktionsdesign er det praktiske og videnskabelig disciplin, der vedrører udformningen af menneskets relation til interaktive digitale systemer. ET litteratur studie fastslog, at hverken Animation eller Interaktionsdesign har et særligt begreb for bevægelse i forbindelse med interaktive digitale systemer. Betegnelsen Funktionel animation foreslås som konceptuel ramme for det overlappende område mellem Animation og Interaktionsdesign. Otte forskningaktiviteter blev udført for at etablere Funktionel animation som et selvstændigt område for forskning og praksis, som kan informere og bliver informeret af områderne Animation og Interaktionsdesign.

En historisk redegørelse for integrationen af bevægelse i Interaktionsdesign viser, hvordan bevægelse har været en del af Interaktionsdesign siden Donald Sutherlands SketchPad-system og at animation første gang, bevidst blev integreret i interaktions design aktiviteter af Alan Kay via Ronald Baecker og animator Eric Martin i udviklingen af Xerox PARCs Smalltalk-system i 1973. Bevægelse har således været en integreret del af WIMP GUI paradigmet siden undfangelsen. Den historiske redegørelse demonstrerer også, hvordan anvendelsen af animation indenfor denne praktiske ramme er en hidtil uerkendt anvendelse af animation. Animation studies bliver analyseret for at positionere Funktionel animation i forhold til andre anvendelser af animation. Dette fører til en model for animations anvendelser, der tillader kortlægning i forhold til animations type (T) og formål (P), og felt (F) og disciplin (D). Denne TPFD-model indeholder en sondring mellem lineær og interaktiv animation. En undersøgelse af animations definitioner fører til en definition af interaktiv animation og den specifikke brug repræsenteret af Funktionel animation: Funktionel animation er kontrol i skabelse, produktion, udførelse, og forbruget af bevægelse, som en ekspressiv komponent, til at formidle mening, i et visuel, interaktiv, brugergrænseflade miljø. Rationalerne for at forstå 'illudering af liv' som essensen af animationen er ligeledes etableret. Disse undersøgelser af animation og tilstedeværelsen af Funktionel animation som en særlig anvendelse af animation suppleres med forslaget af et sæt principper for design af funktionel animation der placerer de kommunikative formål som underordnet eksisterende principper for Interaktionsdesign: Transition, Transformation, Fremskridt, Kvittering, Tip, Opmærksomhed og Illustration. Dette efterfølges af forslaget om en ramme for praktisk anvendelse af disse principper i relation til udvikling af konkrete bevægelses-mønstre, der bygger på den relationelle 'aktion - reaktion' karakter af funktionel animation.

De teoretiske forsknings aktiviteter understøttes af en empirisk undersøgelse, der udforsker betydningen af bevægelse som et selvstændigt fænomen indenfor et interaktivt digitalt system. Undersøgelsen indsamler kvantitative svar fra 188 personer på deres oplevelse af forskellen mellem fem visuelt identiske, men bevægelsesmæssigt forskellige objekter. Undersøgelsen blev udført via en Apple iPad app, der integrerede spørgeskemaet og den praktiske øvelse. Undersøgelsen viser, at folk er i stand til skelne blandt objekter baseret udelukkende på deres bevægelsesmæssige forskelle og dermed at bevægelse som den primære associative stimulans er meningsfuld. Undersøgelsen viser også, at de adspurgte ikke, ud fra en vurdering af materiale og karakterisik, er enige i vurderingen af forskel. Det abstrakte de-kontekstualiserede miljø som øvelsen repræsenterer tilbyder ingen referencer til kendte sammenhænge og dermed viser undersøgelsen vigtigheden og indflydelsen af kontekst, når du udfører tests. Undersøgelsen etablere dermed et empirisk fundament for eksisterende og fremtidige kontekstuelle studier af Funktionel animation.

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I dedicate this work to Johannes =8o) and Asger ~8o) . None above, and none below you. I love you very much and look forward to go spearfishing <*((((--<

Thank you

Morten Lund
Sønder Tranders, October 2016.

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1 OUTLINE OF DISSERTATION

Bad programmers worry about the code. Good programmers worry about data structures and their relationships.
Linus Torvalds, 27.07.2006

The objective of this dissertation is to establish “Functional animation” as the concept for the use of movement as a component in the design of user interfaces for interactive digital systems. The research is grounded in an understanding of interaction design as an interdisciplinary activity that encompasses animation as the skill to control motion as an expressive phenomenon.

The dissertation is a monograph and no articles addressing the objective of the dissertation have been published during the research period.

Initially the dissertation was submitted for assessment december 1st 2015. The Assessment committee suggested that the manuscript be reworkd in accordance to four preliminary recommendations. This second version of the manuscript is a reflection of these recommendations which in summary were to tighten the focus of finding common ground between animation and interaction design via the *functional animation* concept. And to base the research on clear research objectives and integration of the empirical research findings into the theoretical arguments. Adding to this was a recommendation of a structural and stylistic review of the manuscript.

The manuscript has therefore been reworked and now comprise four parts: Part I: An account of the research area, literature review, research questions & activities, and research methods. Part II: An account of the empirical research activity and an analysis hereof. Part III: An account of animation and interaction design as areas of practice with particular emphasis on the common ground. Part IV: A discussion of how the theoretical perspectives and empirical research findings inform the research questions and reach a clear conclusion. Through these four parts the aim is to fulfill the objective of establishing *functional animation* and thereby contribute to both Interaction design and Animation studies.

1.1 PART I - Research setup

Part I establishes the academic setting of the research. A Preface presents some persepctives taht have influenced the project. The research area and central hypothesis is then presented and a literature review leads to eight research questions and related research activities. An account of methodological considerations concludes Part I.

1.2 PART II - Empirical study: The meaning of motion

Part II presents an empirical research study which, based on their motile properties, provide quantitative data on respondents experience of the material and character condition of interactive objects, in a touch screen environment. The study had 220 respondents and collected quantitative data via a questionnaire and a simple task embedded in an iPad App. The research design is explained, the data is presented, analysed and a discussion hereof concludes Part II.

1.3 PART III - Theory: Animation and Interaction design as overlapping areas of practice

Part III address the majority of research questions via an account of five aspects of functional animation. Animation studies are discussed and a model of the area is presented. Definitions of animation are presented and an definition that adress the interactive dimension of functional animation is proposed. The overlapping histories of animation and interaction design are told and the common ground is identified. Finally a unified set of principles of functional animation are presented in concordance with a framework to design, document and communicate functional animation.

1.4 PART IV - Conclusions, discussion and perspectives

Part IV is the final part of the dissertation and will initially discuss implications of the research. This is followed by a summary of the research results in relation to the research questions and thus an evaluation of the research hypotheses. A section on perspectives complete Part IV and the dissertation.

Hopefully, you will, like me, learn a lot more about the relevance of animation in interaction design, and not least the meaning of motion.

2 PREFACE

In 2008, the *Danish ministry of Research and Innovation*[2] approved the Innovation-network *Animation Hub*[3]. Animation Hub was officed at the internationally renowned school of animation *The Animation Workshop* (TAW)[4] in Viborg, Denmark. The purpose of Animation Hub was to explore the potential of animation in contexts that extend beyond the traditional areas of application. The assumption was that animation as a strong communicative medium has have value outside the traditional areas of use and thus the aim was to explore these areas and disseminate knowledge about animation. Five focus area were defined and the area *User*

[2] ufm.dk

[3] en.animationhub.dk

[4] www.animwork.dk/en/

Interfaces was re-cast into a Ph.D. researchproject. The research project named *Animated User Interfaces* was launched January 1st 2010. The project was created as a cooperation between *Animation Hub, Department of Humanities at Aalborg University* and industry partners *Nokia* and *Bang & Olufsen*. Nokia[5] and Bang & Olufsen[6] were already partners of Animation Hub, but chose to support the User Interfaces focus area with extra funding because of their interest in the use of motion in interaction design for touch screen devices. Further details of the project setup and an account of my professional backgroud is found in Appendix F.

This following sections presents some motivational perspectives that have influenced the project.

2.1 Interaction design

The involvement of industry partners represents interaction design from the practical perspective. The possibilities laid out within the Animation Hub Network were promising: Understand the role and potential of movement as part of interaction design, have competitor solutions and own concepts evaluated, and gain knowledge about how to integrate animation in the product development process. But the industry partners did not explicate any specific goals or requirements.

In a business perspective the motivation by the industry partners is found in a growing acknowledgement of user experience (UX) as a competitive parameter. This represents an incentive for implementations that utilise all the tricks in the design toolbox – including animation. A strong motivation would therefore be to understand animation as a component in creating a desirable user experience. Something in particular Nokia had understood when the Apple iPhone was released in Q2 2007. And Bang & Olufsen too, as, e.g. the Apple iPod and iTunes, had been redefining consumption of music.

Information about industry investments in UI and UX are not immediately available at neither a national nor an international level. But Jens F. Jensen (2013) has similar observations about the increased focus on user experience and refer, among others, to Patrick Jordan (2000) who suggest a three level hierarchy of consumer needs that can illustrate this focus: Level 1: Functionality (bottom), Level 2: Usability (middle), Level 3: Pleasure (top) (Jordan, 2000, p.5). As an example, the first Apple iPhone had less functionality (level 1) than contemporary handsets, but the interaction design was a complete novelty (touchscreen) and the device disrupted the global mobile industry. A quick analysis position the iPhone's disruptive power in supporting level 3 consumer needs (pleasure) in an industry that was primarily concerned with level 2 needs (usability). Another perspective on the business value of UI and UX is the mutual patent-lawsuits over level 2 and 3 rights that Apple, Samsung and Google have been engaged in. This indicates that these patents

[5] company.nokia.com/en

[6] www.bang-olufsen.com/en

represent business assets worth defending. Adding to these indicators, reports like Meeker and Wu (2013) show that business trends focus less on the enabling technologies (level 1), and more on the activities enabled and the impact on users lives (level 2 and 3). Meeker (2014) directly list UX and interaction as factors for enabling the ”Big Data Trend”: "Beautiful New User Interfaces – Aided by Data-Generating Consumers – Helping Make Data Usable/Useful" (Meeker, 2014, p.60).

Gaining a competetive edge has therefore been a motivation within the practice dimension of the interaction design perspective. On that front, reality surpassed the project as Bang & Olufsen in 2015 released the *Beosound Moment* which features a touchscreen interaction design heavily reliant on movement (Figure 1). A design conceptualised in cooperation with Seattle based design agency *Tectonic,*[7] which was founded by some of the designers that created the *Microsoft Zune* interface. The Zune interface lay the foundation for the font and tilebased user interface (the Metro design language), now so significant for all Microsofts platforms, and in general the emergence of *flat design*.

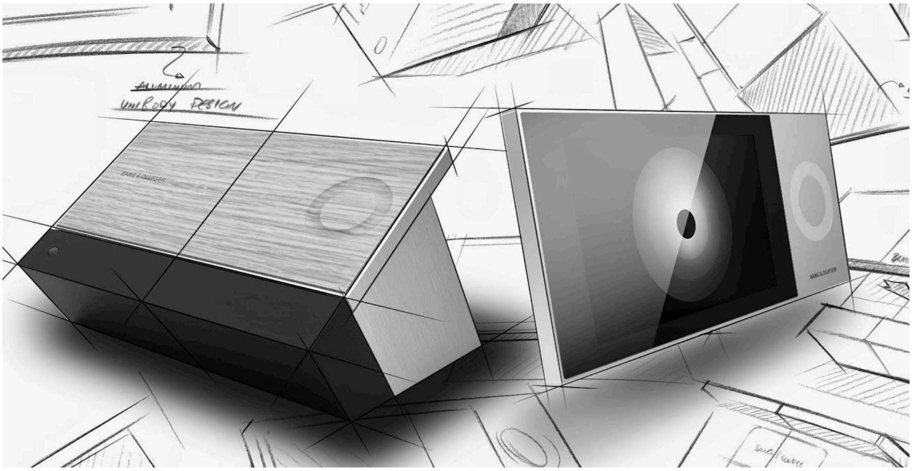

Figure 1. Beosound Moment. Image from bang-olufsen.com

The buiness-driven motivation of Nokia and Bang & Olufsen for entering into this project was reactive to what competitors (Apple, Google) had already proven: That touch screen interaction and App-based device personalisation was successfull. The long term motivation was that the scientific approach would produce knowledge of a general form to inform the business strategy and the creative process shaping new products. Both Nokia and Bang & Olufsen have strong histories of integrating scientific research into their product development strategy and venturing into a research project therefore match their operational modus.

[7] gotectonic.com/#bangandolufsen

But the realities of the mobile marketplace affected Nokia: In 2011 Nokia adopted Microsoft's Windows Phone platform in favour of their proprietary smartphone platforms MeeGo, Maemo and Symbian and in April 2014 Microsoft took over Nokia's handset business. Nokia as a mobile device manufacturer ceased to exist. As mentioned in Appendix F, Bang & Olufsen also lost connection to the project.

The final definition of research questions and activities has therefore been mine and not affected by the project partners. The contributions however, will be valuable to the practical perspective represented by the industry partners.

2.2 Animation

The industry partners and my professional bias as an interaction designer represent a motivational overweight to the interaction design perspective. But as the project originates in the Animation Hub Network agenda of investigating uses of *animation* in areas not usually associated with the use of animation, then the general project motivation, is as much oriented towards animation as it is towards interaction design. The research area equally includes the animation perspective.

The proliferation of animation in user interfaces makes this context an obvious research object for animation studies. The motivation is to extend the theoretical understanding of animation versatility and to expose the requirements of the interaction design context to animation practitioners. Animations studies is an established scientific discipline (Israel, 2007) and animation is a practical discipline taught at schools all over the world – like The Animation Workshop in Viborg. It is therefore a motivation for animation as an area of both research and practice to understand the various contexts of application and the particularities hereof. One of these areas being interaction design. Animation as a creative discipline already extends beyond the typical storytelling usage. Illustrative animations are used for augmenting the news on TV and IBM have showcased technological prowess by creating the world's "smallest" movie by manipulating individual atoms into an animated short: *A Boy and His Atom*[8]. Animation appears to extend the expressive support for presenting and representing information within interactive digital systems. An overlap between requirement (interactive digital systems) and effect (animation) that Ralph Stevenson hinted at in his 1973 definition of animation:

> In animation the film-maker has almost absolute control over his material … in the animated film the artist is more completely freed from the world of reality, limited only by the medium in which he draws, paints, or models, by the structure of the work itself, and by his own imagination. (Stephenson, 1973, p.16-17).

This description of freedom from the constraints of physical reality in creating an artistic product aligns well with Nicholas Negroponte's description of the digital material:

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[8] research.ibm.com/articles/madewithatoms.shtml

> A bit has no color, size, or weight, and it can travel at the speed of light. It is the smallest atomic element in the DNA of information (Negroponte, 1995, p. 14).

Digital technology offers the absolute artistic freedom in terms of allowing combinations of any expressive element with another. The artist just has to use a bit to give the element form. Of course there are constraints in terms of hardware and software capabilities. But the real limit is imagination, as concluded by Stephenson.

Both animation and interaction design stand to gain from an improved understanding of the value of animation. Interaction design is an interdisciplinary field which historically has included the knowledge and practical competencies from several existing fields; and has often returned contributions into these fields. Cognitive psychology and ergonomics were applied as the basis for early HCI, Graphic design has formed the basis for layout of systems interfaces and user-centered design has been developed (Whittaker, 2013). The integration of animation into interaction design will emphasize animation as an independent discipline of practice as this integration is a recognition of the value of animation. This will also illustrate the generic potential of animation and hopefully inspire research in other fields of practice and research where animation is already a part.

As a researcher and interaction designer I will attempt at understanding animation as an independent phenomenon and bring these understandings into relevant perspectives of interaction design. The animation field will potentially gain a broader scope from this research; and interaction design will have added yet an aspect to its interdisciplinarity.

2.3 Personal

My practical experience with interaction design and in particular that of handheld devices has influenced my point of departure for researching animation in terms of research focus and choise of methodological and theoretical approaches.

The peer-review process, debates on methods, and theories of science serve to get as close to objectivity as possible. The process of science serves to verify and validate how research results have been produced. However, despite these formal systems, then methods, theories and communication of research will have a personal and circumstantial dimension which affects the generic value of the knowledge produced. All research, not only in humanities and social sciences, is a matter of the individual researchers moral (Thurén, 2008; Van de Ven, 2007).

The production of knowledge is based on one or more researchers' analysis and interpretation of data collected either via methods that depend on the researcher's presence when obtaining the data (e.g. interview, observation, video), or via methods that obtain data independently of the researcher's presence, but never the less based on the researcher's judgment of appropriateness (e.g. questionnaire, probes, workshops). The auto-ethnographic approach recognise and promotes an active use of the researcher's personal experience and interpretation of the subject-matter. Not as a validating source, but as an aspect that should be explicated as it affects how the project is defined, scoped, executed and concluded. In an overview paper, Ellis, Adams and Bochner (2011) phrases it as follows: ”Consequently, autoethnography is one of the approaches that acknowledges and accommodates subjectivity, emotionality, and the researcher's influence on research, rather than hiding from these matters or assuming they don't exist” (Ellis et al. 2011, p. 274). Van de Ven (2007) comes from the perspective of critical realism and supports this view:

> No form of inquiry is value-free and impartial; instead each model and perspective is value-full. This requires scholars to be far more reflexive and transparent about their roles, interests, and perspectives when conducting a study than they have in the past. (Van de Ven, 2007, p.14).

The auto-ethnographic approach brings further transparency to how knowledge comes to be by highlighting the researcher's personal presence in the research. Not only by describing the methods and theories involved, but by explicating the researcher’s personal experience, motivation and stance in the scientific process. The subjectivity becomes a methodological strength.

Personal matters can however be difficult to retain and communicate. An auto-ethnographic text should be personal, describe the culture experienced and contain points of epiphany in the narrative (Ellis, et al, 2011). The account of my professional and personal experience with interaction design and animation in Appendix F does not qualify as an auto-ethnograhic text by those qualities. It is better described as an auto*biographic* text. For this reason I will not claim an auto-ethnographic approach and neither do I consider it a suitable method for this project. But I will, inspired by the auto-ethnograhic ethos, highlight a couple of personal motivations for having undertaken this research and how these have influenced my approach.

My understanding of design, and in particular interaction design, is founded in practical experience. This has affected my evaluation of the methodological and theoretical understandings that I have come across, as I have an ”is-this-useful” mindset. My beliefs have also affected which approaches and perspectives that I prefer, because they support and/or extend these beliefs. I view design as a constructive activity which at its core is about *control of the different components* that constitute the final product. This view has had an impact on my approach and thinking in this project. I view movement as such a component and would like to understand how movement fits the existing set of interaction design components. As a designer I would like to know how to work with this component. These personal, but yet professionally grounded motivations, match the motivations described for the industry and animation perspectives. As a researcher I must therefore ensure that the approaches are guided by scientific methods and not personal convictions.

My strictly personal motivation for this project is to merge and extend my interaction design experience with the fascination and understanding of movement as a vehicle for conveying meaning and creating wonder that has grown out of this project.

2.4 Summary

The motivational perspectives presented have in different ways affected the project. The industry partners provided a lot of momentum at the project outset. They also supported functional animation as the project goal. The animation perspective has come to take up much more space in the final dissertation than expected as the establishment of functional animation is as much a contribution to animation studies as it is to interaction design. As for my personal motivations, then they have been fulfilled.

PART I
SETTING THE SCENE: STAGING AND ANTICIPATION

If it moves, it is alive
Filmmaker Segey Eisenstein, n.d.

Design is a plan for arranging elements in such a way as best to accomplish a particular purpose.
Industrial & Graphic designer Charles Eames, 1989

3 INTRODUCTION PART I

In Part I, five sections are presented: The research area and the central project hypothesis (section 4). Following this I will briefly address the semantics of animation and movement (section 5). A literature review (section 6) will lead to definition of research questions and research activities (section 7). The final section of Part I will address the methodological approach (section 8).

4 RESEARCH AREA & HYPOTHESIS

This research project was established in the context of Animation Hub on the assumption that animation in the context of designing interactive digital systems represents a not exhaustively investigated area and that such an investigation will bring out an unacknowledged potential. A potential that will benefit the field of animation as well as the field of interaction design.

The Animation Hub project's motivation is found in the proliferation of movement in all types and areas of contemporary computing that involves screen-based human computer interaction: operating systems, creative and productivity applications, web-sites and on-line systems, operating systems and apps for mobile devices, gaming platforms, embedded systems and kiosks, art productions, etc.. In every area it is possible to find human computer interaction patterns that incorporate movement as part of communicating system functionality and facilitate dialogue with the user. The inclusion of movement also appears to proliferate independently of interaction modalities: mouse, keyboard, touchpad, touchscreen, gestural, game controller, etc.. Statistical evidence hereof was provided by my investigation into the presence of movement in 5 different handheld touch-screen devices, across 30 different interface patterns. This study documented movement in 79% of the 150 patterns (Appendix C and Appendix D). Jon O.H. Eikenes (2010, p.2) uses similar observations as motivation for his research, but do not present any data to support the observation.

The project is constituted by two equally important perspectives: The interaction design perspective and the animation perspective. By the interaction design perspective, I refer to the body of knowledge and creative processes that produce interactive digital systems. By the animation perspective, I similarly refer to the body of knowledge and creative processes that produce animation. This project is located in the overlap between animation and interaction design. I propose the term *functional animation* as reference for this overlap. The contents of the overlap will define functional animation. Therefore the research area of this project is functional animation and the research aim is to establish the contents hereof. The research hypothesis is consitituted by the following statements:

> *Statement 1) The context of interactive digital systems constitute a particular use of animation.*

Statement 2) The interactive and task-oriented nature of interactive digital systems makes this use of animation significant compared to other contexts of use.

Statement 3) Animation as the craft of manipulating motion, and movement as the resulting phenomena, are fundamental to the quality of this interaction.

Statement 4) The term Functional Animation is proposed for this particular use of animation.

The functional animation concept has grown out of my research and did not exist prior to this project. Jon O.H. Eikenes (Eiknes, 2010) suggests *navimation* and *kinetic interfaces*, as concepts for human computer interfaces with motile properties. But these concepts do not include animation as the creative force of movement in the interface. The term *functional* is proposed as it appears significantly descriptive of animation in the context of interactive digital systems. Interactive systems are characterised by the dialogue between user and system. The dialogue has a task-oriented, functional objective and animation is a component in facilitating this dialogue. *Functional* therefore refers to both the context of use and the role of animation in this context. The term functional animation is also suggested for this use of movement by Daliot (2015).

This is a scientific project and therefore at the outset aimed at building theory via scientific methods. But the project setup with industry partners implies that the research should also be relevant to their practical setting. This perspective is not a disadvantage as this science-practice connection should ensure that the research does not fall into the so-called *theory-practice gap* where the research advances neither science nor practice (Van de Ven, 2007). The science-practice connection also situates the project well within the tradition of Problem Based Learning (PBL) practiced at Aalborg University.

Andrew Van de Ven (2007) describes the relationship between science and practice: ”To say that the knowledge of science and practice are different is not to say that they stand in opposition or they substitute for each other; rather, they complement one another” (Van de Ven, 2007, p.3). This complementary nature constistutes an iterative interrelationship where science and practice exchange knowledge in the form of theory. Science evolves theory by researching practice and existing theory. Practice evolves theory via application to specific problems that require contextual solutions, and thus challenge these established understandings. Figure 2, is a model of the project perspectives, animation and interaction design in relation to respectively science and practice: animation as science and practice, and interaction design as science and practice. In between is the overlap that constitutes the research area: functional animation

	Animation (A)	Overlap A & ID	Interaction design (ID)	
Science	Animation studies		Interaction design studies	**Science**
	Animation theory	*Functional animation*	Interaction design theory	
Practice	Animation production		Interaction design production	**Practice**

Figure 2. The basic perspectives of the project and how these constitute the research area.

In the perspective of establishing a scientific contribution, Figure 2 illustrates how theory – about the area *functional animation* – is established in the interrelationship between science and practice. Elements from the four different perspectives convene into a common theoretical target of establishing functional animation.

In the following section I will briefly address the semantics of the terms animation and movement. Following this, a literature review will present the first research activity and provide a status on the publicly available body of knowledge within the research area. An evaluation of this status will establish the research questions and activities required to further establish functional animation.

5 ANIMATION VS. MOVEMENT

In some contexts of design the term ”motion graphics” is used. This covers the use of motile graphic elements in a usually commercial context. In the introduction to her 2016 book ”Animated Storytelling – Simple Steps for Creating Animation and Motion Graphics” Liz Blazer writes: ”Animation and motion graphics have been kept apart, and yet these two forms have much in common and so very much to learn from one another.” (Blazer, 2016, p. n.a.). From the book it is quite clear that the two disciplines are very similar and the precise difference seems to relate to genre and animation skills applied in creating motion. This emphasis on *motion* as the shared denominator between the two areas of practice, and *animation* as a set of skills to create motion of a certain quality, point to a semantic separation of the craftsmanship from the result; and the necessity for proper terminology for this separation: Animation as the craft and motion the result. Applying animation creates motion.

The balance in terminology can be hard to maintain as illustrated by the following quote from well-established mobile interaction designer Rachel Hinman[9]. In her book, ”The Mobile Frontier” chapter 7 (out of 9) is dedicated to ”Motion and animation” by the following argument:

[9] From book cover: Rachel Hinman is currently Senior Research Scientist at the Nokia Research Center in Palo Alto, California. Before Nokia: Experience Design Director at Adaptive Path, and a Mobile Researcher and Strategist for Yahoo’s Mobile Group (Hinman, 2012).

> The addition of artful animation has all but invaded the mobile user experience field. Whether it is the transitions between screens of a mobile experience or the behaviors applied to UI elements that can be interacted with using gestures, motion has become a significant mobile design element. (Hinman, 2012, p. 183)

Hinman uses two references for her subject: ”artful animation”, ”motion … a significant mobile design element”. She seems to define *Motion* as an element of mobile design – something to integrate into the user interface concept and *animation* appears to be an overall term for this type of design element. But this is my interpretation and the difference is not quite clear from the text. A lack of clarity is also apparent in the chapter title: ”Motion and animation”. The chapter summary includes an almost tautologic reference to ”Transitions and subtle motion-based animations” (Hinman, 2012, p. 201). This is an extreme example of the challenged use of the terms animation and motion. But inconsistent use is also found in academic and other practice literature where *animation* refers to both the skillset and the result of applying this skillset. For clarity it is therefore necessary to distinguish between the skillset and the creative process on one side and on the other side, the resulting motile qualities in an object or media product to be perceived and experienced by a user or audience.

In this project I preserve the term *animation* for the skillset and activity of creating motion for a mediated context. Whereas the terms *movement, motion* and *motility* will refer to the phenomenon and result of applying animation.

The separation of movement and animation could be problematic as the animator’s skillset is required to work (professionally) with motion. But separation is only established to avoid ambiguity. Not to define which of the two to address in this research. Animation and motion are equally relevant to the research area. The animators skillset represents an understanding of motion which is necessary to establish the rationale for functional animation. Central is the 12 animation principles (Thomas & Johnston, 1984), which makes possible the artistic installment of movement into otherwise immobile objects. Understandings and principles, that form the basis for practicing animation, will be addressed in Part III.

This definition of terminology and concepts supports statement 3 of the functional animation hypothesis (section 4).

6 LITERATURE REVIEW

This literature review will present current state of the art research within the overlapping area of interaction design and animation. The literature review is the first research activity as it provides a literary baseline of the overlap. The publications included are the texts found relevant for defining the area of functional animation based on their addressal of movement within the area of interaction design. Based on this it will be possible to build further research. Both within this project, and within future projects.

The literature comprises both scientific publications and texts originated in practice. This is to cover the ”theory-practice gap”. The scientific publications were identified in three ways: 1) Aalborg University Library Primo database searches on the keywords: user Interface + animation, user Interface + movement, Interaction design + animation, and Interaction design + movement, and similar searches in the ACM Digital Library and IEEE Xplore databases; 2) reviewing the reference lists of individual texts and 3) non-structured encounters. I do not claim the list to be definitive, but the observed cross-reference among the publications makes me confident that these represent state of the art.

The practice originated texts were identified via web search and subsequent browsing, via newsletters, RSS and other push-services, and via references from colleagues, students and friends. They do by no means represent the full set of practice originated texts on motion in user interfaces. But they are representative of the types and quality of practice originated texts. These texts do, in a few cases, refer to scientific publications, but most appear to represent idiomatic compilations of best practice. The practice originated texts also include company style guides. Style guides are different from other texts as they do not offer generic guidelines and principles. These documents are directives for *how something must be done* in order to create a certain expression. The style guides represent finite design decisions and thus an evaluation of what works within this particular system context. The style guides of the dominant interface styles represent interesting statements about state of the art. Not experimental prototypes, but well iterated and field-tested solutions.Table 1 provides a chronological overview of the 58 texts constituting the literature review. The table represents the existing knowledgebase and an analysis hereof will indicate where new research will be valuable. The table has six columns:

1) *Year* of publication
2) *Numbering* for easy reference of entries in the subsequent analysis
3) *Author and title* enable lookup in Bibliography (section 26)
4) *Type* of publishing channel
   a. Book
   b. Bookchapter
   c. Ph.D. dissertation
   d. Jounal paper
   e. Conference Paper
   f. On-line
5) *Category and description* of content. The description summarises the contributions of the text. Categories describe the primary focus of the text. Seven categories were identified during the review:
   a. *Design*
   Movement as a component for interaction design: Rationale, Principles and Guidelines.

b. *Animation*
Considerations from the animation perspective on interactive digital media.
c. *SW Architecture*
How to engineer software to integrate movement into the user interface.
d. *Framework*
How to describe and communicate movement.
e. *Process*
How to integrate animation into the design and development process.
f. *Tools*
Description of tools for prototyping and/or implement movement.
g. *Case*
Description and evaluation of specific uses of movement.
h. *Concept*
Description and evaluation of user interface concepts.

6) *Platform.* The user interface platform addressed in the text
   a. WIMP: Graphic User Interfaces based on Windows, Icons, Menus & Pointers.
   b. TOUCH: Handheld devices with touch screen interaction
   c. WEB: UIs for WWW
   d. OTHER: Platforms not among the above

In Table 1 ”animation” is abbreviated to ”A” and ”interaction design” to ”ID”. Entries marked with an * are texts originated in practice.

Year	No.	Reference	Type	Category & Description	Platform
1963	**1.**	Sutherland, Ivan Sketchpad: A Man-Machine Graphical Communication System.	Ph.D. dissertation	*Design, SW Architecture, Framework, Concept.* Conceptualisation and realisation of the Sketchpad system allowing zooming, paning and moving and stretching of screenbased objects. First graphic user interface and object oriented programming.	OTHER
1964					
…					
1968					
1969	**2.**	Baecker, Ronald Interactive Computer-Mediated Animation.	Ph.D. dissertation	*Design, SW Architecture, Framework, Concept.* Conceptualisation and realisation of the GENESYS system allowing animators to realise animation in a fully digital environment. Animator Eric Martin is involved.	OTHER

1970					
1971					
1972					
1973	**3.**	Baecker, Ronald Towards Animating Computer Programs: A First Progress Report.	Jour. paper	*Design, Tool.* An account of the efforts into creating visual representations of program routines and their relations. Dynamic visuals are well suited for this purpose as they allow handling of time and abstraction. The goal is to generate animated tutorial movies from these visuals.	OTHER
1974					
…					
1980					
1981	**4.**	BYTE Magazine 1981, Vol.06, No.08 Smalltalk	Book	*Design, Concept, SW Architecture, Process.* The entire volume is dedicated to the description of Smalltalk-80. Smalltalk was the systems to realize both object oriented programming and the WIMP user interface. Both concepts build on the same metaphor of making information manipulation direct.	WIMP
1982					
1983	**5.**	Heckel, Paul Walt Disney and User-Oriented Software – Mickey Mouse teaches software designers a lesson	Bookchapter	** Design, Process.* Presents 6 interaction design principles based on the 12 animation principles from Thomas & Johnston, (1984): 1) Make it interesting, 2) Exaggerate reality, 3) Think in visual terms, 4) Prepare the audience, 5) Don't crowd the screen, 6) Involve the audience. The iterative Disney process is compared to the SW dev. process.	WIMP OTHER
1984	**6.**	Birss, Edward W. The integrated software and user interface of Apple's Lisa	Conf. paper	*Concept.* Description of UI features and design and technology rationale behind these.	WIMP
	7.	Myers, Brad A.	Jour. paper	*Concept.*	WIMP

		The User Interface for Sapphire.		The ICL PERQ Sapphire UI is described. Overlaying, resizable, moveable, windows. Progressbar. Pop-up menus. Contemporary to the Xerox STAR and Apple Lisa and Macintosh systems. Sapphire was the first commercially available WIMP system.	
1985	**8.**	Myers, Brad A. The Importance of Percent-Done Program Indicators for Computer-Human Interfaces	Conf. paper	*Case.* Empirical study that demonstrates the end-user value of dynamic graphic progress indicators.	WIMP
1986					
1987					
1988					
1989	**9.**	Robertson, George G.; Card, Stuart K.; & Mackinlay, Jock D. The Cognitive Coprocessor Architecture for Interactive User Interfaces	Conf. paper	*SW Architecture.* Presentation of the Cognitive Coprocessor that enable (screenbased) interactive, animated, 3D information visualisations. Purpose is to enable access and overview over large quantities of data.	OTHER
1990	**10.**	Baecker, Ronald; & Small, Ian Animation at the Interface	Bookchapter	*Design.* Rationale for using A in the UI. Typology of UI A, and examples of animation in the user interface to reveal: Structure, Process, and Function.	WIMP OTHER
1991	**11.**	Baecker, R; Small, I; & Mander Bringing Icons to Life	Conf. paper	*Case.* An empirical study that investigates the value of animating icons to explain and demonstrate the functionality represented by the icon.	WIMP
	12.	Card, Stuart; Robertson, George G.; & Mackinlay, Jock D. The Information Visualizer - an information workspace	Conf. paper	*Concept, SW Architecture.* A 3D UI platform for inf. presentation, navigation and retrieval as an alternative to the Desktop metaphor. Using A to support Gibson's theory of active perception. Based on Robertson, Card & Mackinlay (1989).	OTHER

	13.	Chatty, Stephane Defining the dynamic behaviour of animated interfaces	Conf. paper	*SW Architecture.* Based on a visual metaphor the Whizz system enable integration and control of UI A in relation to three categories of A.	WIMP OTHER
	14.	Mackinlay, Jock D.; Robertson, George D.; & Card, Stuart The Perspective Wall: Detail and context smoothly integrated	Conf. paper	*Design, Concept* Presents the 3D Perspective Wall concept for integrating the space strategy and the time strategy for information presentation and navigation, in one view on a 2D screen. Animation is used to rotate ”the wall”. Based on Card, Robertson & Mackinlay, (1991).	OTHER
	15.	Robertson, George D.; Mackinlay, Jock D.; & Card, Stuart Cone Trees: Animated 3D Visualizations of Hierachical Information	Conf. paper	*Design, Concept* Presents the 3D Cone Tree concept for accessing large information spaces. Animation is used to rotate the view and thus reduce cognitive load by allowing visual perception to follow the repositioning of information. Based on Card, Robertson & Mackinlay, (1991).	OTHER
1992					
1993	**16.**	Chang, Bay-Wei & Ungar, David Animation: From Cartoons to the User Interface	Conf. paper	*Design, Concept* Empirical study of implementing the 12 animation principles of Thomas & Johnston (1984) to interface elements in the Self system. Cognitive and affective end-user benefits are found. Some user test. 3 principles for UI animation are presented: Solidity, Exaggeration and Reinforcement.	WIMP
	17.	Hudson, Scott; & Statsko, John Animation support in a User Interface Toolkit: Flexible, Robust and Reusable Abstractions	Conf. paper	*SW Architecture.* Implementation of some of the 12 animation principles of Thomas & Johnston (1984) into the Artkit SW development environment is presented.	WIMP
	18.	Kay, Alan C.	Conf. paper	*Design, SW Architecture,*	WIMP

		The Early History of Smalltalk.		*Concept.* Describes the conception and development of the first WIMP based GUI: Smalltalk at Xerox PARC. Reveals why and by whom animation was integrated herein: In 1972 Ronald Baecker and animator Eric Martin visits PARC.	
	19.	Robertson, George G.; Card, Stuart; & Mackinlay, Jock D. Information Visualization Using 3D Interactive Animation.	Jour. paper	*Design, SW Architecture, Concept*. Presentation of 8 different animated, interactive 3D information spaces. The end-user value of these UI concepts for information access, retrieval, sharing and manipulation is discussed. Based on Robertson, Card & Mackinlay, (1989]	OTHER
	20.	Stasko, John T. Animation in User Interfaces: Principles and Techniques.	Bookchapter	*Design, Framework, SW Arch.* Provides contemporary state of the art status of both design and implementation of UI A. Presents 4 design principles: Appropriateness, Smoothness, Duration/control and Moderation. 4 contemporary cases for animation of Icons, Help, Process and Navigation are presented.	WIMP
1994	…				
1995	**21.**	Smith, Randall B.; Maloney, John; & Ungar, David The Self-4.0 User Interface: Manifesting a System-wide Vision of Concreteness Uniformity and Flexibility.	Conf. paper	*Design, Concept, SW Architecture.* Porting characteristics of physical reality will benefit the computing experience. 3 characteristics: Concreteness (Moving of solid windows w. drop shadow, slide in of contextual objects, drag n' drop of functions, shrink as feedback on action, pop-up menus), Uniformity (consistency of behavioural	WIMP

				principles across system) and Flexibility (concreteness and uniformity support flexibility at the UI level and further is added by Self specific object oriented principles) offers a feeling of liveness and more immediate feedback and thus a sense of the physical world. Self tries to do for a programming language what the Desktop metaphor did for common computing.	
	22.	Thomas, B.H.; & Calder, Paul Animating Direct ManipulationInterfaces	Conf. paper	*Design, SW Architecture.* Describes the motivation and approach to applying A to interface objects later developed in Thomas (1998) and extended and detailed in Thomas & Calder (2001). The goal is to obtain the illusion of manipulating ”real” objects.	WIMP
1996	**23.**	Myers, Brad A.; Miller, Robert C.; McDaniel, Rich; & Ferrency, Alan Easily Adding Animations to Interfaces Using Constraints.	Conf. paper	*SW Architecture.* Presents the constraints based Amulet toolkit for easier modularization and reuse that enables attachment of A to existing UI widgets and objects.	WIMP
	24.	Vodislav, Dan HandMove: a system for creating animated user interface components by direct manipulation.	Bookchapter	*SW Architecture.* Overview of existing architectures. Presents the HandMove system for direct manipulation build of animated ”scenes” to be integrated as UI elements. Thus making the creation of UI A accessible to non-programmers. Part of Ph.D and work extended into Vodislav & Vazirgiannis (2000).	WIMP
1997	**25.**	Chui, Michael; & Dillon, Andrew Who’s Zooming Whom? Attunement to Animation in the Interface	Jour. paper	*Case.* End user test of the associative effect of the MacIntosh folder to window open/close ”zoom” behaviour. No evidence of associative effect is found,	WIMP

				but the movements positive effect on user experience is exposed.	
	26.	Bartram, Lyn Can Motion Increase User Interface Bandwidth in Complex Systems?	Conf. Paper	*Design, Framework.* The UI bandwith problem (screen size for data) is introduced as motivation for including A. Provides UI A state of the art status. Introduces ecological interface design where system function knowledge is obtained perceptually rather than cognitively. A research agenda for motion in the interface is presented. Based on existing research a preliminary taxonomy of motion as a dimension of communication is proposed: Kinetic primitives, Motion types & Motion use.	WIMP WEB OTHER
	27.	Bodner, Richard C.; & MacKenzie, Scott Using Animated Icons to Present Complex Tasks	Conf. paper	*Case.* A user-based comparative study of static vs. animated icons for a texteditor and a spreadsheet. Animated icons provide a higher preference and rate of recognition of function in relation to both feature complexity and user proficiency. Test is not interactive and out of program context.	WIMP
	28.	Vodislav Dan A Visual Programming Model for User Interface Animation	Conf. paper	*SW Architecture, Framework* Repetition of Vodislav (1996), but with emphasis on the framework for describing UI A types: Spontaneous, Interactive and Application-controlled	WIMP
1998	**29.**	Thomas, Bruce H. Animating Direct Manipulation in Human Computer Interfaces	Ph.d. dissertation	*Design, Case, Concept, Framework, SW Architecture* The study presents contemporary state of the art and unifies known aspects in a proposed technical prototype that is	WMP

				user-tested. It is concluded that ”animation effects are effective and enjoyable for users”.	
1999					
2000					
2001	**30.**	Thomas, Bruce; & Calder, Paul Applying Cartoon Animation Techniques to Graphical User Interfaces	Jour. paper	*Design, Concept* User tests are performed on a drawing editor prototype to test enhancements in the perception of direct manipulation when motile qualities are added to screen objects. 4 principles for animating direct manipulation are presented. Based on PhD dissertation (Thomas, 1998).	WIMP
2002	**31.**	Robertson, George; Cameron, Kim; Czerwinski, Mary; & Robbins, David Animation Visualization of Multiple Intersecting Hierarchies		*Design, Case, SW Architecture.* An extension of Robertson, Card & Mackinlay (1993). Presents the concept of ”Polyarchy” for datasets comprised of multiple separate databases. An animated visual pivot allows the user to maintain overview when navigating the data. User studies and surveys are used to modify the concept.	OTHER
2003					
2004					
2005	**32.**	Klein, Christian; & Bederson, Benjamin B. Benefits of Animated Scrolling	Conf. paper	*Case.* The user based study presents data that show a subjective preference and objective efficiency value of continuous scrolling of documents compared to ”jump-based” scrolling.	WIMP WEB
	33.	Skjulstad, Synne; & Morrison, Andrew Movement in the interface	Jour. paper	*Design, Case.* From the activities of designing an on-line Flash site some general observations on the convergence of form and content via spatial and kinetic dynamics are	WEB

				presented. The interface is seen as communication and the need for a new aesthetic is suggested.	
2006					
2007					
2008	**34.**	Wells, Paul & Hardstaff, Johnny Re-Imagining Animation – The Changing Face of the Moving Image	Book	*Animation*. Considerations on the impact of digital media on the animated form. A few mentions of animation in interactive contexts.	N.A.
2009	**35.**	Eikenes, Jon O.H. Social Navimation - Engaging Interfaces in Social Media	Conf. paper	*Design, Case.* Focused on social media to explore the capability of dynamic interfaces to enhance engagement. Presents the general concepts ”indexical compositing” and ”virtual kinetics”. Presents principles specific for dynamic interfaces for social media.	WEB TOUCH
2010	**36.**	Eikenes, Jon O.H.; & Morrison, Andrew Navimation: Exploring Time, Space & Motion in the Design of Screen-based Interfaces	Jour. paper	*Design, Case.* A socio-semiotic approch is taken to present, and test via prototypes, the concept Navimation as the intertwining of visual movement with navigation activities in screen environments. Core concepts are: Temporal navigation, Spatial manipulation and Motional transformation.	WEB TOUCH OTHER
	37.	Eikenes Jon O.H., Connecting motional form to interface actions in web browsing	Jour. paper	*Design, Case* Presents the concept ”motional form” for the use of movement in interfaces and suggest 10 principles for the use of motional form in web-browsing. Suggest that movement conveys meaning through the use of connotations and experiential metaphors.	WEB
	38.	Eikenes, Jon O.H. Navimation: A socioultural exploration of kinetic	Ph.D. dissertation	*Design, Framework, Case.* A comprehensive account and contribution to the	WIMP WEB

		interface design.		area. The focus is how movement characterises the communicative dimension of the interface. Proposes the concept Navimation for motion augmented navigation in information spaces and Kinetic interfaces for UIs that have movement as a key characteristic. Research by design approach. Design principles are presented.	TOUCH OTHER
	39.	Park, Doyon; & Lee, Ji-Hyun Investigating the Affective Quality of Motion in User Interfaces to Improve User Experience	Conf. paper	*Design, Case, Framework.* Two studies. 1) Aim to direct users emotional response (experience) via control of the affective qualities of motion. Introduces Labans nomenclature for body motion to design interactive objects. Quantitative test w. 20 subjects on 3 interactive prototypes show that motion type influence affective quality of the interface, but content and context must also be considered to predict users response. 2) 8 motions are quantitatively tested by 20 students for their ability to properly perceive and map the motile properties and parameters. The test confirmed the usefulness of the terms for describing motion properties and parameters.	WIMP
2011	**40.**	Harrison, Chris; Hsieh, Gary; Willis, Karl D. D.; Forlizzi, Jodi; & Hudson, Scott E. Kineticons: Using Iconographic Motion in Graphical User Interface Design.	Conf. paper	*Design, Framework.* Presents the concept Kineticons, an iconographic scheme of motions to consistently apply motile properties to objects and events across different states and functions of a UI. A user-tested vocabulary is presented.	WIMP WEB TOUCH
	41.	Novick, David; Rhodes, Joseph; & Wervyn, Wert	Conf. paper	*Design.* Based on a survey, by the	WIMP WEB

		The Communicative Functions of Animation in User Interfaces		authors, of A in a broad variety of Uis, 7 types of UI As and 7 communicative functions are presented. The appropriateness for effectiveness in the UI is then estimated in a matrix setup.	TOUCH OTHER
	42.	Park, Doyun; Lee, Ji-Hyun; & Kim, Sangtae Investigating the affective quality of interactivity by motion feedback in mobile touchscreen user interfaces	Jour. paper	*Design, Case.* The research of Park, Doyon; & Lee, Ji-Hyun (2010) is recapitulated and extended with test on a pressure force sensitive display prototype. The added dynamic of force significantly increases the affective quality and the physical feel of the interface.	TOUCH
2012	**43.**	Hinman, Rachel The Mobile Frontier	Bookchapter On-line[10]	** Design, Case, Process.* Relates touch and web to NUI. Refers to motion as a ”design material”. Rationales for UI A are: clarity, inf. about context & a ”dash of joy and fun”. The 12 animation principles by Thomas & Johnston, (1984) are presented and comments, guidelines and examples for their use in designing interactions are provided for each. Realism in UI presentation is purported as a desired effect. Comments on integration into process of sketching, wireframing, and prototyping. Well illustrated. No references.	WEB TOUCH
	44.	Mirlacher, Thomas; Palanque, Philippe; & Bernhaupt, Regina Engineering Animations In User Interfaces	Conf. paper	*Framework* Presents a two level model for specifying UI A to bridge the gap between design and implementation. High level description of motile properties and composition	OTHER

[10] Chapter also available at Smashing Magazine: www.smashingmagazine.com/2012/10/motion-and-animation-a-new-mobile-ux-design-material (accessed October 2016).

				of objects; and relation to other objects and system events. Low level description of precise behaviour and timing.	
2013	**45.**	Schlatter, Tania; Levinson , Deborah Visual Usability: Principles and Practices for Designing Digital Applications	Bookchapter	** Design, Case.* Two brief sections within lager chapters about types of imagery and revealing affordances. Two non-exclusive categories are suggested: Communicate details & Personality and Motion of interface elements to reveal information, provide feedback & reinforce relationship. Four high level questions for applying A. Mention of motions ability to draw attention and show progress.	WIMP WEB TOUCH
2014	**46.**	Nabors, Rachel The State of Animation 2014	On-line	** Design.* An introduction to the value and practical application of A in web-design. 3 types of UI A defined as dependent on their complexity and thus technical ditto. Centered around SVG, CSS and aims to introduce the 3WC Web Animation API. One academic reference: Hudson & Stasko (1993).	WEB
2015	**47.**	Daliot, Amit Functional Animation In UX Design	On-line	** Design.* Presents UI A as Functional Animation. Presents 9 types of FA based on their ”logical purposes”: Orientation, Same Location, New Action, Zoom In, Visual Hint, Highlight, Simulation, Visual Feedback, System Status, Marketing Tool. The typology is suggested as a tool for reflection. Video examples included. No academic references.	WEB TOUCH
	48.	Bruni, Ezequiel The ultimate guide to Web	On-line	** Design.* Presents5 types of web A: 1) Interface element, 2)	WEB

	animation		Waiting, 3) Story-telling, 4) Decorative, 5) Advertising. Guidelines for design and implementation. List of various resources. No academic references.	
49.	Drasner, Sarah Practical Techniques On Designing Animation	On-line	** Design, Process.* A set of high level guidelines for why’s and how’s of UI A. Suggest seeing the object as a character. Suggest treating A as any other design component in the design process: mock-ups, color-palettes, storyboards, wireframes and composition. No academic references.	WEB
50.	Cao, Jerry; Cousins, Carrie; Zieba, Kamil; & Stryjewski, Krzysztof Interaction design and Complex Animations	On-line	** Design, Tools.* First half describes various trends in ID for web and touch. Movement is an integrated part and mentioned explicitly throughout the text. Second half focuses on UI A. Presents the 12 A principles of Thomas & Johnston (1984). 5 core functions of UI A: 1) Communicating function, 2) Revealing information, 3) Distraction, 4) Storytelling, 5) Pacing. Some future trends for web-A are proposed. 9 Types of generic animated elements are presented. Link to various ressources. Academic references.	WEB TOUCH
51.	Cao, Jerry; Zieba, Kamil; & Ellis, Matt Interaction Design Best Practices 2: Mastering Time, Responsiveness & Behaviour	On-line	** Design, Tools.* 3 Strategies for UI A are presented: A) Distract Users During Loading Time , B) Transition & Inform Users via 5 uses: 1) Notifications, 2) Revealing Information, 3) Highlighting content, 4) Collapse forms/menus, 5) Scrolling., C) Follow the 12 principles of Thomas & Johnston	WEB TOUCH

				(1984). Link to various ressources. No academic references.	
	52.	Cao, Jerry; Cousins, Carrie; & Riddle, Ryan T. Mobile design - Book of trends 2015-2016	On-line	** Design, Tools.* Presents, among other things, Google Material design, Flat design, and Micro-interactions. In all of these A is highlighted as an intrinsic design component. Guidelines on design and implementation. No academic references.	WEB TOUCH
2016	**53.**	Di Sciullo, Mark How To Integrate Motion Design In The UX Workflow	On-line	** Design, Tools, Process.* Relates UI A to the design process. Recommends aligning UI A to specific user needs and present 13 ”key functions” of UI A. Presents the elements for a UI A design process. The process is in alignment with a std. Agile Ui process. Presents extensive list of UI A prototping tools. No academic references.	WIMP WEB TOUCH
	54.	Yalanska, Marina Interface Animation. The Force of Motion	On-line	** Design.* Presents high level guidelines for why’s and how’s of UI A. Defines 4 types of A in ID: 1) Animation enabling microinteraction. 2) Animation showing the path of the process. 3) Clarifying/explanatory animation. 4) Decorative animation. Video examples. No academic references.	WIMP WEB TOUCH
	55.	Guidelines for Universal Windows Platform	On-line	** Design.* Brief rationale and 3 purposes are presented followed by 5 benefits: 1) Add hints towards interaction, 2) Can give the impression of enhanced performance, 3) Adds personality, 4) Adds consistency, 5) Adds elegance. A catalogue of 7 types is listed (Add and delete, Drag and drop, Edge, Fade, Pointer, Pop-up	WIMP WEB TOUCH

			animations, Reposition) with links to more specific guidelines and implementation advice. Static examples. No academic or external references.	
56.	Google Material design	On-line	** Design.* Uses the term ”motion”, not ”animation”. Purpose statment: to describe spatial relationships, functionality, and intention with beauty and fluidity. Aims: Guide focus between views, Hint at results of user actions, Hierarchical and spatial relationships, Distraction, Character, polish, and delight. Material motion characteristics: Responsive, Natural, Aware, Intentional. Material movement qualities: Quick, Clear, Cohesive Animated examples for all statements. No academic or external references.	WEB TOUCH
57.	Apple Inc. iOS Human Interface Guidelines (Beta)	On-line	** Design.* Uses both terms ”motion” and ”animation”. 3 overall iOS themes are presented: Clarity, Deference and Depth. The last two explicitly mention motion. Rationale and purpose: Beautiful, subtle animation builds a visual sense of connection between people and content. A can convey status, provide feedback, enhance the sense of direct manipulation, and help users visualize the results of their actions. Presents 3 principles: 1) Use consistent A, 2) Use A and motion effects judiciously, 3) Strive for realism and credibility. Animated example. No academic or external references.	TOUCH

58.	Apple Inc. OS X Human Interface Guidelines	On-line	** Design.* Uses the term ”animation”. Goals of UI A: Give feedback and help users understand the results of actions; Enhance clarity and communication. 9 principles: 1) Avoid gratuitous A, 2) avoid using A as focus of the UX, 3) Use A to clarify the consequences of user actions, 4) Animate a window's transition to and from full screen, if appropriate, 5) Aim for realistic motion, 6) Use A when an object changes its properties, 7) Use A when an action occurs so quickly that users can't track it, 8) Avoid animating routine actions supported by system-provided controls, 9) Avoid animating everything. Static example. No academic or external references.	WIMP

Table 1. Overview of texts included in literature review.
Animation is abbreviated to ”A” and interaction design to ”ID”.

The following conclusions are based on the publications presented in Table 1. The publications will be referenced by the number in column 2. This is done for reasons of readability. Full author and publication title and thus bibliographical reference is available via column 3. Publication details are found in the Bibliography (SECTION 26).

The majority of the 58 publications represents interaction design. This is also reflected in the eight categories: *Design, Animation, SW Architecture, Framework, Tools, Process, Case*, and *Concept*. Animation is only represented by one category and one publication [34]. This skewed perspective indicates that animation studies and animation practitioners, at least within the dissemination of their discipline, are not aware of interaction design as an area of relevance for study and practice. Establishing functional animation therefore seems like a valuable contribution to the animation discipline.

The interaction design literature within the overlap constitutes 57 publications. 15 of these are practice originated: [43] and [45-58]. This means that 42 publications constitute the academic study of movement in interaction design. Within these, 9 publications establish a complementary core of the area: [5], [10], [16], [26], [33],

[30], [38], [40] and [42]. These all primarily address the design perspective. [38] is the Ph.D. dissertation of J.O.H.Eikenes (Eikenes, 2010) and includes [35], [36] and [37] as these form the basis for the dissertation. The remaining 30 publications are relevant for historic reasons or because they address a case specific application of movement. 17 of these primarily address SW architecture [1], [2], [4], [9], [12], [13], [17-24], [28], [29] and [31]. I have included none of these among the core publications as the dominant subject is how to engineer sw that allows the integration of movement into the user interface. These publications do include design-considerations, but sw architecture is their primary objective. [29] is the 1998 Ph.D. dissertation of Thomas Calder and includes both [22] and [30]. [30] is among the 9 core publications. [30] was published in 2001, 3 years after the dissertation, but reports the design specific findings from the dissertation prototype test. It is one of the three most referenced texts within functional animation. The other two are [10] and [16]. An interesting observation is that no publications concerning sw architecture are registered after year 2002. [31] being the last. [31] is about an architecture specific for interactive information visualization. [29], which is from 1998, would therefore be a more appropriate last reference for research into animation sw architectures. After 2002 the publications concern *design, case, concept* and *framework* and then in 2014 the subject *tools* and *process* appear. 2014 is where the first practice originated on-line texts are brought into the review. The technical dialogue has shifted from creating sw architectures that support animation to tools that allow designers to work with animation within these architectures (primarily web-based). Tools are for either prototyping or implementation. Practice originated on-line texts probably exist prior to 2014 and backtracing would show when sw reached a maturity that made tools more relevant for implementing movement than the underlying architecture. The publications [9], [12], [14], [15], [19], [26] and [31] represent the interactive information visualization perspective on movement. [9] is from 1989 and presents the challenge to the information society of how to access, navigate, manipulate and understand massive amounts of information. In particular when the screen has a 2 dimensional limit. The solution is to research 3D environments where the user's overview and mental model is supported by adding motion to the navigation of visual data structures. The work is summarised in [19] and then picked up again in 2002 [31] by one of the authors from the original studies. [26] is from 1997 and refers to the information visualization problem as the "UI bandwith problem". But this study focuses solely on motion and not on specific implementations and thus provides a 1997 state of the art status within motion in the user interface. This publication is among the core publications and must have been available to both Thomas Calder and J.O.H.Eikenes for their Ph.D.'s, [29] and [38], but is not referenced by either. [26] is written by Lyn Bartram and she actually consolidates the area with this publication. [38] from 2010 also provides a solid overview and represents a substantial contribution to the area. But [38], Eikenes (2010), has a socio-semiotic approach to the user interface and does not reflect upon the relation to animation as an independent field. His focus is on how movement characterises the communicative

dimension of the user interface. This is a contribution to the perspectives of prior and following publications which have a cognitivist or affective approach. [20] covers state of the art to some extent, but is 23 years old and not very relevant for GUIs anno 2016 nor UIs for web and touch. [40] from 2011 provide an overview similar to [26] and test an arbitrary set of cases for motion in GUIs to establish the concept ”Kineticons”. No recent publication accumulates the state of the art and presents a collected set of guidelines and principles.

All publications until 2005 [33] are focused on the use of movement in WIMP environments. Except those focused on information visualization. If not focused on SW architecture then these pre-2005 studies focus on specific WIMP concepts [6], [7], [18] and [21] or specific WIMP cases of use like progress feedback [8], animated icons [11], [27], window resizing [25] and scrolling [32]. After 2005 web and touch become part of the scientific research scope. Only [42] explicitly address touch from a scientific perspective. [33] and [38] explicitly address www from a scientific perspective. The practice originated texts are focused only on web and touch [43] and[45-58].

The practice originated texts, from either design magazines or design company blogs (all on-line), [46-54] exhibit a professional practitioner’s understanding of how and why to include movement in interaction design. They contain almost no academic references, but they generally communicate sound practical advice, and appear in agreement with one another. Similarly for the styleguide documents [55-58]. The practice originated texts also contain very good and up to date examples on use of movement. Some of them interactive. The academic publications present theoretical rationales, models and terminology that match practice, but are not referenced by practice. It is mainly the reference to the 12 principles of animation that they share (Thomas & Johnston 1984). The practice originated texts use the terms animation and motion inconsistently whereas recent scientific publications focus on the phenomenon motion and not the artistic skillset animation.

The styleguide documents [55-58] all underline the importance and proliferation of movement in contemporary interaction design. These documents represent interaction design concepts which reach billions of users as illustrated by the Q1 2016 sales numbers presented in Table 2. Smartphone sales represented 78% of total mobile phone sales in Q1 2016. There is a 3,9% overall increase in sales compared to Q1 2015.

Operating System	Q1 2016 Millions of units	Q1 2016 Market Share (%)	Q1 2015 Millions of units	Q1 2015 Market Share (%)
Android	293.771.200	84,1	264.941.900	78,8
iOS	51.629.500	14,8	60.177.200	17,9
Windows	2.399.700	0,7	8.270.800	2,5
Blackberry	659.900	0,2	1.325.400	0,4
Others	791.100	0,2	1.582.500	0,5
Total	**349.251.400**	**100**	**336,297.800**	**100**

Table 2. Gartner research: Worldwide Smartphone Sales to End Users by Operating System in Q1 2016. www.gartner.com/newsroom/id/3323017

The sales numbers are not an argument for the use of movement. The numbers show that these user interfaces are commercially successful and to reach these levels of popularity, then they have matured in mutual competition. This competition has resulted in stylguides that all present movement as a top-level design component. Apple's iOS Human Interface Guidelines [56] have motion included into two of the three overall themes for the UI concept (Deference and Depth). This extensive use of movement in interaction design anno 2016 is also apparent in the on-line practice originated texts [46-54]. My own investigation also supports this proliferation (Appendix C).

It appears as if academia and practice are not syncronized, that the theory practice gap exists. Practice uses, un-referenced, rationales found in 10-20 year old academic research, primarily on WIMP GUIs. Or they use idiosyncratic understandings, for *extensively* applying movement in the design of contemporary web and touch-based interactive systems. But practice is designing successful solutions. The challenge is therefore to make academia align with practice and create a common ground that will advance both.

The literature review documents that movement in the user interface indeed *has* been researched, has a history, and that movement is an important component in interaction design. Valuable publications *have* appeared since sw architectures matured around year 2000. But the emphasis on movement by contemporary design practice is not matched by the scientific effort reflected in publications. No substantial academic text has been published since 2011 [40]. Web and touch is not very well represented in research publications within the area, but has a pronounced presence in the practice originated texts. Rationales and terminology are not syncronised as scientific rationales and terminology appear further advanced than those found in practice.

The area appears fragmented as no recent publication unifies the existing research or provides an agenda for future research. Within animation the area is non-existing. The project objective of establishing functional animation therefore represents a valuable contribution to both animation and interaction design. This concept will, if consolidated in science and practice, not only contribute to the area, but establish the area. The concept will constitute a point of departure and reference for future research and practice.

7 RESEARCH QUESTIONS

The literature review was the first research activity for establishing functional animation. The existence of literature in the area is in itself a manifestation of functional animation. But the review also confirmed that movement is an important component in contemporary interaction design. The area, however, appeared fragmented and therefore functional animation will be valuable as a common concept of reference between practice and science within animation and interaction design (see Figure 2).

The objective is therefore to define which research activities will unify and consolidate the overlap and thus establish functional animation.

The literature review points to eight research questions and associated activities:

7.1 Q1 Animation studies

The absence of publications from the animation perspective that address the context of interaction design indicates that animation studies are not aware of interaction design as a context of animation use. Therefore, the question to address this absence is:

How does functional animation position itself in relation to other uses of animation?

An account of animation studies will be presented to address this question in section 16. This activity concerns statements 1 and 2 of the functional animation hypothesis (section 4).

7.2 Q2 Animation and interactivity

The interactive context represented by functional animation is different to popular uses of animation that present a linear narrative. The task-oriented character of user interfaces might also challenge established definitions of animation. The question to address the interactive perspective is:

Does the interactive context require a different understanding of animation?

An account of animation definitions will be presented to address this question in section 17. This activity concerns statements 1 and 2 of the functional animation hypothesis (section 4).

7.3 Q3 Overlap in histories

The literature review reaches back to the early 1960'ies and reveals how movement and gradually animation has been entwined with the history of interaction design.

This common background is important to describe as this illustrates how the overlap is not an academic construction, but an area grown out of a design practice. This account will help unify the area and establish functional animation as an area in its own right. The history of animation in interaction design is also important to understand the rationales behind this inclusion and thus why movement is in the user interface. The question to address the common history is:

What are the rationales for including animation and movement in interaction design?

An account of the history of animation and the rationales for movement in the interface presented in the literature, will address this question in section 18. This activity concerns statements 1, 2 and 3 of the functional animation hypothesis (section 4).

7.4 Q4 Unification of design principles

The fragmentation detected in the literature study is particularly manifest in the areas of teminology and design principles. I have briefly addressed the issue of teminology in section 5. Almost every design publication proposes a unique set of principles. This proliferation of different principles supports the fragmentation of the area. Collecting, reviewing, merging and pruning the rationales, principles and guidelines for the use of movement therefore represents a valuable contribution to establishing functional animation. The question to address functional animation design principles is:

What are the design principles for functional animation?

An account of design principles and a unified set of principles will address this question in section 19. This activty concerns statements 1, 2 and 3 of the functional animation hypothesis (section 4).

7.5 Q5 Framework for design and documentation

Only one publication [44], (Mirlacher, Palanque & Bernhaupt, 2012) addresses frameworks for designing, documenting and communicating the design of movement within the design and development process. The principles and understandings of motion presented in other publications suggest alternative approaches to such a framework. A framework would make the creative use of design principles more accessible and operationalise functional animation to interaction designers and animators. The question to address a framework for functional animation is:

How could design principles manifest a framework for design, documentation and communication of movement in the design and development process?

Based on the existing principles a framework will be proposed in section 20. This activity does not address any statements of the functional animation hypothesis, but does add to the overall establishment of functional animation.

7.6 Q6 The meaning of motion

The research activity reported in Appendix C and studies like [41], (Novick, Rhodes & Wervyn, 2011) made me aware that case studies do not produce findings that will necessarily have a generic quality. One way to generate generic understandings, is to ask fundamental questions. Therefore, I designed a survey that had respondents quantitatively report their subjective experience of 5 visually identical, but motionally different objects, during a simple interactive task, presented on an Apple iPad. The purpose was to answer the following quesion:

Does motion generate meaning?

The findings of this empirical study are reported in Part II. This activity concerns statements 1, 2 and 3 of the functional animation hypothesis (section 4).

7.7 Q7 & Q8 Implications and research agenda

Through the research findings based on the prior six questions, two additional questions present themselves. These are questions that I will address in the Discussion (section 22) and the Perspectives section (section 24). These questions are:

What are the implications of functional animation for interactive digital systems?

What is the research agenda for functional animation?

These eight questions and related activities are meant to support the hypothesis presented in section 4 and thus constitute functional animation as an independent area of research and practice.

7.8 Summary

To illustrate the possible research contributions and implications of functional animation, I present Figure 3, which utilises the framework presented in Figure 2. Establishing functional animation equals building a theory of functional animation. This theory is informed by the interrelationship between science and practice. The scientific aspect will constitute the rationale for functional animation and the practical aspect will constitute the guidelines for functional animation. Areas which are both addressed in the research activities.

	Animation (A)	Functional animation (FA)	Interaction design (ID)
Science	1) Extend scope of field 2) Recognition of A within ID		1) Extend Interdisciplinarity 2) Understand potential of A in context of ID
Theory	FA theory building	Establish concept: 1) Rationale for A in ID context 2) Guidelines for A in ID context	FA theory building
Practice	1) Extend scope of application 2) Extend curriculum for teaching institutions		1) Competetive edge 2) Improve User Experienece 3) A as component for ID

Figure 3. Model of research area as defined by research activities and possible implications. Modified version ofFigure 2.

The elements within the disciplines constitute the elements of the overlapping area. This overlap is where functional animation emerges. The establishment of functional animation is therefore both the establishment of 1) an independent area and 2) an identification of specific areas within respectively a) animation and b) interaction design.

In the literature review, touch interaction and web stand out as areas lacking recent scientific research But for the purpose of establishing functional animation, a focus on web is not required. Anecdotal experience however, indicates that web-access is one of the activities much used on touch enabled smartphones and tablets. Addressing touch interaction will therefore indirectly also addresses web interaction. The popularity of touch enabled devices already mentioned and the presence of movement in 79% of the patterns documented in the study of touch devices (Appendix C) indicates that movement in touch interaction is very important. The interaction design paradigm Natural User Interfaces represents an understanding of interaction design that integrates touch interaction and builds on an approach to interaction design separated from the WIMP GUI paradigm (Wigor & Wixon, 2011). The Natural User Interface paradigm will frame the discussions of my research findings in section 22.

8 METHODOLOGY

Design is the overarching field of this dissertation. Interaction design of digital systems is the practical discipline and research focus specifically on the use of movement as a component for interaction design. Movement is researched as both a phenomenon, a practice and an effect. The perspective upon design is within the user-centered tradition of interaction design (Whittaker, 2013).

In the foreword to Löwgren, and Stolterman (2004) Pelle Ehn writes: ”Design theory is not a scientific theory in the narrow sense of predicting the outcome of an action irrespective of context and situation. Instead, it is concerned with transforming the conditions and potentials for human action …”. He progresses to compare this understanding to the Aristotelian concept *phronesis*: ”… an action-oriented and context-dependent design theory based on practical value rationality" (Löwgren & Stolterman, 2004, p. viii). This focus on human action and context is an imperative within interaction design and could be viewed as a defining trait. Jonas Löwgren states it very aptly in the online Encyclopedia of Interaction Design: “People’s use is what interaction design shapes digital things for” (Löwgren, n.d.). This shaping of things happens in the design process which by Terry Winograd’s definition “… is at work in creating the individual pieces and relationships that make up the whole” (Winograd, 1996, p.xx). A view which builds on Christopher Alexander, the father of design patterns: “… the process of design; the process of inventing things which display new physical order, organization, form, in response to function” (Alexander, 1964, p.1). This understanding of design makes movement a component in the design of digital artifacts for people’s use. Animation is the creative discipline that designs movement by manipulating the aspects constituting the motile component.

This project is a design research project and the research performed contributes to both animation and interaction design theory on why and how to apply movement (Figure 3). This will be collected in the common concept functional animation.

Researching design could be approached from a variety of perspectives and by a variety of methods. Liz Sanders establishes a map (Figure 4) of two intersecting design research perspectives. One is the approach: *Design* or *Research*. The other is the mindset: *Expert* or *Participatory* (Sanders, 2008). The map covers both a ’science-practice’ perspective and an ’empirical-methodological’ perspective and allows me to explain how this research project is positioned within these perspectives.

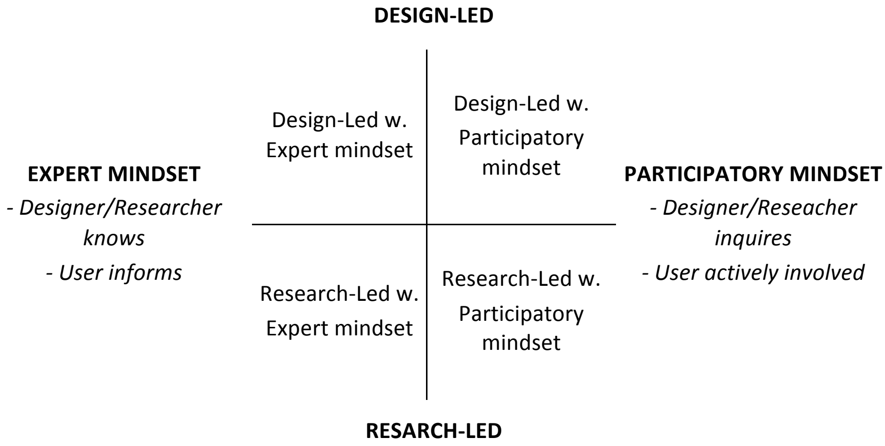


Figure 4. The design research map. Sanders (2008).

The horizontal axis presents two different mindsets towards 1) knowledge about the domain of interest and 2) how users within this domain are perceived. The axis concerns methodological approaches to empirical activities. *The Expert mindset* positions the researcher/designer as knowledgeable experts about the domain. This could be viewed as a positivist position. Users are reactive informers who will be consulted about the domain if the researcher/designer finds this useful. The *Participatory mindset* positions the researcher/designer as knowledgeable, but not as a domain expert. The domain experts are the users who will be actively involved in research and design activities. This position could be seen as pragmatic or relativistic.

The vertical axis presents the ’science–practice’ perspective. This is not entirely within the definitions provided by Sanders (2008), but she does not define ”design-led” properly and research could also be a design-activity (Frayling, 1993). The *Design-led (practice)* perspective is the practical perspective where designers intervene into the area of interest via explorative processes. The aim is to generate novel designs: ”Both critical design and generative design aim to generate and promote alternatives to the current situation” (Sanders, 2008, p.3)[11]. Within this perspective designers generate knowledge about practice and apply their professional competencies. The *Research-led (science)* perspective is the scientific perspective where the goal of activietes is to develop theory and guidelines for practice to have a professional foundation.

According to Christopher Frayling,”Science is much more like doing design” (Frayling, 1993, p. 7). This statement follows a discussion of different practices and purposes of research in relation to design and art, and lead to three approaches of

[11] ”critical” and ”generative design” are types of design approaches discussed within the design-led perspective.

research in connection to design (and art). Jonas (2012) provides an extensive analysis of design research and characterise Frayling's approaches: "We think that this categorization, which – for the first time – does not distinguish as to subject matter or an assumed structure of the "real world" but according to purpose, intentionality and attitude towards subject matters in design, is essential for a genuine designerly research paradigm" (Jonas, 2012, p. 20-21). These three approaches exist in parallel along the 'researcher–designer' axis in Sanders (2008) model (Figure 4). A modification of Sanders' model could integrate Frayling's approaches and thus provide more nuance for mapping the activities in this project. This modification is illustrated by Figure 5.

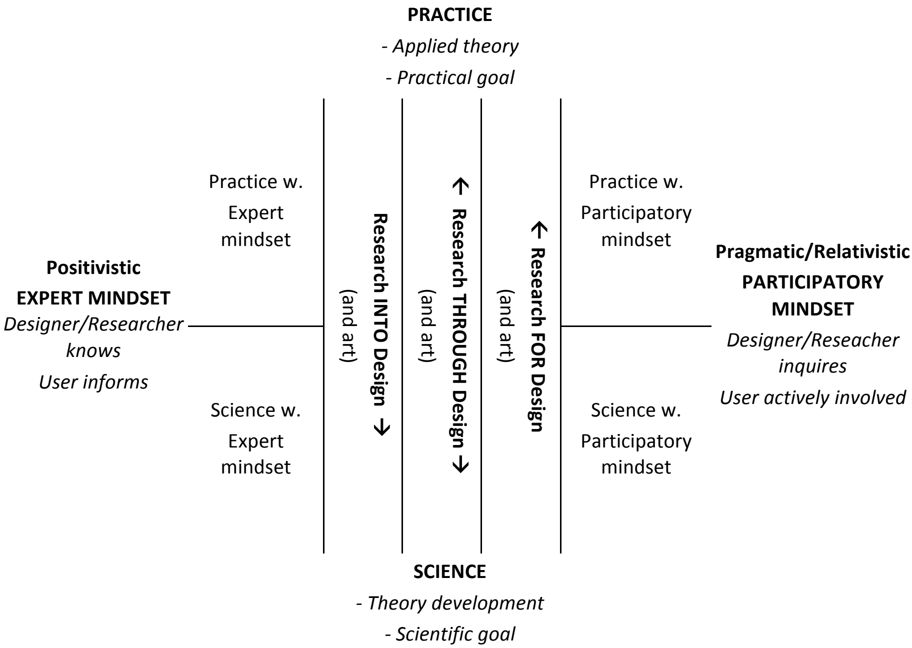


Figure 5. Integration of Frayling (1993) into Sanders (2008) and modification to reflect the vertical axis as 'science-practice'.

The three approaches integrated into Sanders' (2008) model are as follows:

Research into design (and art) is research, which addresses the design practice from the scientific perspective. The purpose is to understand the practice and build theories and develop methods. This approach may address both design practice and design theory, but the result will be theoretical.

Research through design (and art) is research which uses design activities to generate insights and understandings about the research domain. Frayling (1993) actually mention Action research as an example of this approach where the designer-researcher intervenes into the research domain by purposely influencing the domain and through this intervention gather data and knowledge. The designer-researcher is not only an observer, but also an active participant within the domain.

Research for design (and art) is research which serves to inform the creative process towards a designed product or an artistic form. This could be informal and exploratory investigations of different materials or scientific projects to inform complex products (Frayling, 1993).

There are two important observations regarding these categories of design research. One is that research is not confined to either science or practice. The other is the orientation of these approaches. Research *into* design has a scientific perspective and research *for* design has a practice oriented perspective. Research *through* design however, is *both* scientific and practice oriented. Furthermore, research through design is not a perspective, but an experimental methodology which is (could be) used to generate data for both research *into* design and research *for* design. Research through design activities could be directed at domains within both practice and theory and results contribute to either.

The scope of this project covers both science and practice as explained via Figure 2, but the contributions will be theoretical (Figure 3). These theoretical contributions will have no practical value until applied in practice. This will then serve to further modify the theories. The overall perspective of the research is therfore research into design.

A research hypothesis was formulated as the project setup represented a clear interest from the stakeholders. The hypothesis is meant to guide the research questions and activities (Andersen, 2013).

The hypothesis scoped the literature review which was the first research activity (section 6). This was a scientific research into design activity within the expert perspective. The inclusion of practice oriented texts represented the practice perspective and served to soften the scientific dominance upon understanding the research domain. The review itself could be characterised as a critical reading towards describing current state of the art within functional animation. This critical reading resulted in eight research questions which each represent a problem within the area of research.

Research question 1, 2 and 3 are addressed via scientific inquiries into the existing understandings of animation in the perspective of movement in interaction design. This is therefore research into design in perspective of the researcher as expert. This research is based on a critical and synthetic reading of existing literature and the inclusion of literature from outside animation studies. The results are theoretical contributions which will primarily impact the academic community, not practitioners; unless the findings affect teaching curricula.

Research questions 4 and 5 are addressed via scientific inquiries into existing understandings of movement in interaction design via an analytical reading of the literature in the literature review. This is therefore research *into* design and the perspective is the researcher as expert. However, the ambition is practical as the goal is to propose guidelines for how practice should work with movement in interaction design. My personal background is also that of the practitioner, and from that standpoint then these activities could be seen as research *for* design. Never the less, the contributions are theoretical. The inclusion of publications that originate in both practice and research moves the research towards the middle of the empirical axis, but the analysis of these texts is performed by the expert researcher.

The theoretical developments are complemented by an empirical study which extends the development of functional animation theory beyond analysis of existing theory.

Research question 6 is addressed via an empirical study into movement as a phenomenon in relation to interactivity. This study collects data via a quantitative survey on the experience of motion in an interactive digital setting. The study includes an exercise which respondents then report via the survey. The study is research *into* design as the goal is the building of theory. This theory building concerns both functional animation as an independent area and guidelines for the application of functional animation in interaction design. The orientation is therefore both *into* design and *for* design: 1) The study provides an empirical foundation for establishing functional animation, but this is research *into* design as the goal is scientific in the sense that theory is built to define a particular phenomenon. 2) Like the analytical activites for research questions 4 and 5, then the ambition is to inform and influence practice via improved understandings of the effect of movement and thus how to design with movement. In that perspective, then the research is *for* design, but the result is theoretical.

The empirical study has two dimensions. One is the actual reporting which is handled by a questionnaire. The other is the phenomenon respondents are asked to report. The phenomenon is movement and to generate an experience to report, then respondents perform an exercise on an Apple iPad. The study is phenomenological in the sense that data is collected on the subjective experience of interactive movement and not evaluated against fixed parameters related to a certain purpose of the actions performed within the exercise - e.g. usability. This phenomenological approach makes the study explorative as the approach allows results to both diversify and/or converge the understanding of movement.

The phenomenological and user-centered perspective also informed the study design as both potential respondents and animators participated actively in shaping the study. This means 1) that the phenomenon (movement), reflect the design domain (animation), within the study and 2) the questionnaire questions reflect possible reactions collected in cooperation with the the respondents group. The actual execution of the study happened ”in the wild” and without researcher presence as the questionnaire and exercise were packaged into an Apple iPad app. On the axis of empirical perspectives, the study is located towards the participatory mindset, but the analysis of data is performed by the expert researcher.

Methodologically, then the questionnaire study represents an instance of quantitative phenomenological research, reporting on movement as an interactive digital phenomenon. The study results are based on a descriptive analysis and not a particular theoretical perspective. Giorgi (1992) defines a descriptive approach to data as ”…the use of language to articulate the intentional objects of experience within the constraints of intuitive or presentational evidence” (Giorgi, 1992, p. 121). The descriptive approach is applied to allow the data to present movement as a phenomenon in the interactive context without any other context of understanding than that of how movement was meaningful to the study participants.

Research questions 7 and 8 are addressed in the discussion and perspectives section and conclude the dissertation.

This methodological account could have utilised Daniel Fallmann’s *Interaction Design Triangle* (Fallmann, 2008), but the combination of Sanders (2008) and Frayling (1993) allowed positioning of the research activities along the methodological axis, a perspective missing from (Fallmann, 2008). A futher analysis of Fallmann vs. Frayling may also reveal an overlap in orientations as Fallmann’s *Design exploration* and *Design Practice* are similar to research *into* design via e.g. research *through* design methods; and Fallmann’s *Design Studies* is similar to Frayling’s research *into* design. Frayling’s research *for* design is similar to design activites within Fallmann’s *Design Practice*. But these considerations are research into design/design studies not within the scope of this project.

PART II
LOOKING AT REALITY: EXAGGERATION, SLOW IN & SLOW OUT

Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question, which can always be made precise.
John Tukey, 1962

9 INTRODUCTION PART II

Part II reports an empirical study that addresses research question no. 6: *Does motion generate meaning?* (section 7.6). Answering this research question concerns statements 1, 2 and 3 of the functional animation hypothesis (section 4). The hypothesis directing this study is:

Motion, as the dominant characteristica, is capable of instilling meaning in the individual, interacting with a motile digital object, in a touch environment.

Empirical data to address the hypothesis and research question was collected via a questionnaire survey that had respondents quantitatively report their subjective experience of moving 5 visually identical, but motionally different circles onto a location marked by a cross (Figure 6). The technological platform was the Apple iPad and both survey and exercise were integrated into an iOS App that respondents installed on their private iPads.

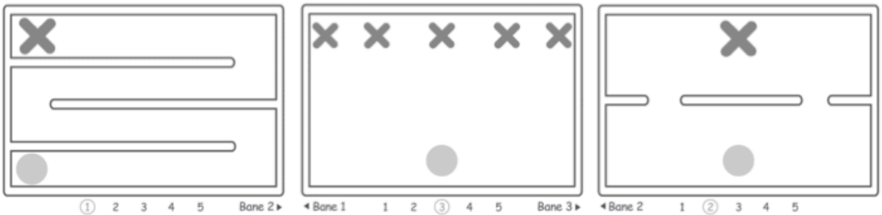


Figure 6. The three courses where respondents had to move five versions of the cicle to the location of the cross.

I will refer to this empirical research activity as ”the study”.

The App is no longer available via the Apple App.-store, but download to iPad is possible via http://hugelawn.com/beta/AnimUI2-1.0-78-Debug/.

The study design and results are reported as follows: This Introduction leads to an account of the selected technological platform (section 10). This is followed by descriptions of the activities producing the final study design, including a description of the questionnaire (section 11). The results are presented and discussed in section 12. This concludes Part II.

The initial research activity (2010), about the presence of motion in contemporary handheld touch devices, reported in Appendix C was the inspiration for this study. The review of these devices showcased the many different ways the same UI pattern could include motion and highlighted how motion could be innovatively used in patterns not necessarily covered in a research setup. This generated the methodological challenge of how to generate insights into the experience of motion that were *independent* of specific interactive digital system contexts.

If data could be generated on the experience of motion independently of a system context, but still in an interactive digital environment, then this would present the *foundation for contextual usages of motion*. This became the research aim of this empirical study: The meaning of motion in an interactive setting, but independently of any system context.

The study will create the foundation for functional animation in terms of providing empirical data on movement as a phenomenon, and as a design component for interactive systems, that is meaningful to the user. This foundation will support existing research (section 6) and allow further work to establish a contemporary set of guidelines and principles for functional animation (section 19.2) and a ditto creative framework (section 20).

10 TECHNOLOGICAL PLATFORM

Touch was selected as technological platform for three reasons:

1) The focus of the industry partners was on touch interaction. It was discussed to conduct studies on a somatosensory feedback display. But this was rejected as the prototype display was not available and the somatosensory dimension would obscure the focus on motion. Park, Lee and Kim (2011) reports a study of a force sensitive touch display and concludes that this technology has potential, but also makes design more complex. Respondents are not in favour as the prototype lacked tactile feedback.

2) The increasing proliferation of touch devices and the speed at which the uptake was happening made it relevant to research interactivity on this platform (section 2.1).

3) The literature review identified a lack of research on movement in the context of touchscreen interaction.

The Apple iPad was selected to represent touch interaction. The iPad appeared to be the most widely available tablet, at the time of research definition (2011/12). The tablet format was chosen as smaller devices like the Apple iPhone and Apple iPod Touch were too small for properly presenting the questionnaire. Designing the environment for two device sizes also represented a ressource challenge and would from a scientific perspective represent two independent studies. This decision was also support by empirical activites reported in section 11.

The iPad platform also implied some methodological advantages: Data generation (exercise) and data-collection (questionnaire) could be integrated in the same environment (an iOS App) and the Apple App-store both simplified, accelerated and increased distribution of the study to possible respondents.

In hindsight, then the hype of the Apple iPad (released in 2010) might have influenced the choice of this device. But the hype possibly also had a positive influence on the study as it may have increased interest in contributing to the study and the overall dissemination of the App.

The iPad hype also included a risk of respondents associating their positive/negative views on this new and innovative device into activities taking place on this device. This was one of the reasons why the exercise designed for the study (Figure 6) did not have any stylistic or interactive references to the Apple iOS look n’ feel. Nor did the environment have references to other commercial platforms. The interactive environment sought to anonymize any brand values.

Conducting the study across multiple technological platforms (WIMP, gaming platforms, etc.) was never part of the scope as it would require resources not supported by the project budget.

11 STUDY DESIGN AND EXECUTION

This section presents the activities that led to the final study design and describes the data collection activities.

The design activities was constituted by three primary components: 1) Designing the exercise for respondents to perform to generate comparable data on motion (section 11.1), 2) Defining the questionnaire to collect data on the exercise (section 11.4), and 3) Designing and developing the iPad iOS App that integrated exercise and questionnaire (section 11.2).

The latter activity constituted a software development process where requirements had to be settled and refined, the design iterated upon via sketches, flow-diagrams, prototypes and stakeholder, and developer meetings, followed by implementation and functional tests leading to approval by the Apple App-store and final release and dissemination activities.

The exercise performed by respondents to generate data (Figure 6) is central to the study as it embodies the study motivation, research question and hypothesis. The actual process of designing and synthesising the study and exercise idea into a functional whole was not the linear process presented in this section. As within all design processes, then the components affected one another in an iterative process of elaboration and convergence (Buxton, 2007).

11.1 Exercise design

The first incarnation of the exercise design was a visual ”proof of concept” created in Adobe Flash by an engineer at Nokia, Oulu, in June 2011 (Figure 7). The mock-up did not work on iPads as Flash is not supported by this platform. But the mock-up was very useful for illustrating the idea and thus move into the next iteration that further refined the requirements.

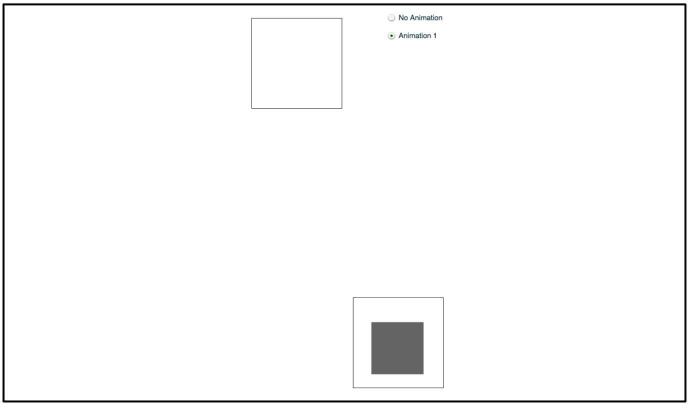


Figure 7. First interactive mock-up of the exercise to be used for generating data. Created by Ashley Colley, Nokia, 2011.

Next iteration was five participatory design sessions in November 2011 with non-research colleagues from a neighboring department: 2 women and 3 males aging 25-45 of which the four were younger and had academic schooling. The sessions were inspired by the user-centered design methodology as described by e.g. Holtzblatt, Wendell and Shelley (2005) and conducted in one day, at my office, which offered the necessary space and privacy. An interview-guide was prepared (Kvale, 2007). The Danish only interviewguide is available in Appendix B. To document the sessions and collect insights video and written notes were used[12].

The participants had no prior knowledge of my study subject, but this was without relevance as the purpose of the sessions was to openly discuss the ability of the study design to generate data on the experience of movement.

The basic question for the sessions was: ”Would you, as participant in this study, believe it possible to report data on the motile qualities of digital objects, in a touchscreen environment? If not, then how should the exercise be designed to enable this?”.

The aims of the sessions were to collect 1) requirements for the exercise design and 2) requirements for which data to collect to inform the hypothesis (section 9) and 3) requirements for how to collect this data. Also the hypothesis was not as precise at the time, so this activity also helped pinpoint the hypothesis and research question. But his was an outcome that presented itself during and after the sessions, and not an explicit aim.

The sessions served as verification and falsification of my pre-understandings and established an empirical basis for the study design. To facilitate discussion then a setup for experimenting with the exercise design was created (Figure 8).

[12] available upon request to mlund@hum.aau.dk

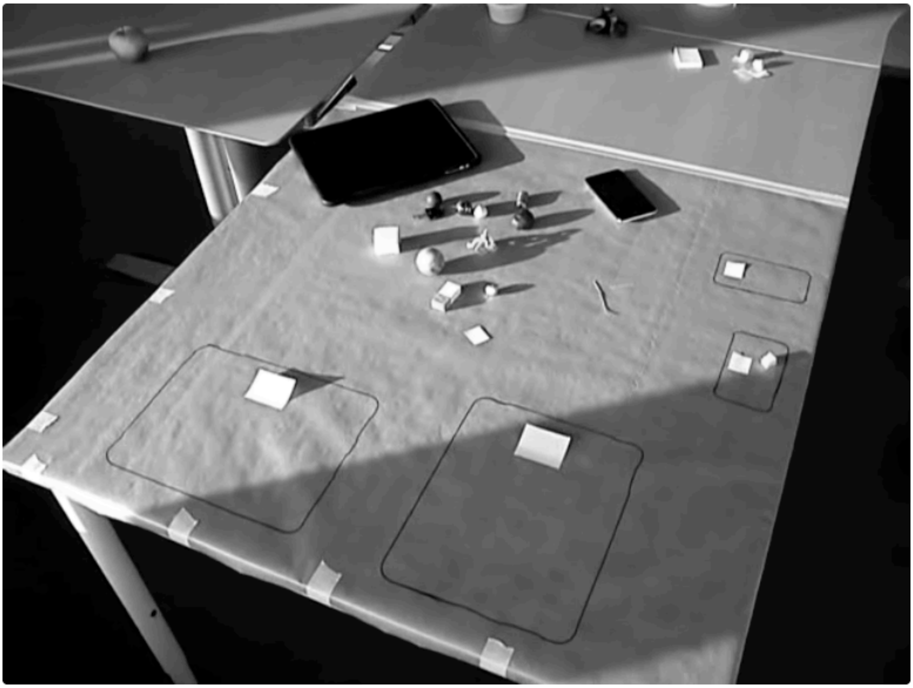


Figure 8. Setup for participatory design sessions.

A large piece of brown paper was attached to a tabletop and the outlines of an Apple iPad and an iPod Touch were drawn in respectively landscape and portrait orientation. This was to simulate the display area and have correct measures hereof. Using the actual devices was not realistic as they rocked and skidded on the table. Within the device-outlines a small post-it was placed to indicate targetarea. Post-its were used to alow the target area to be moved if the design experimentation required this.

Objects have different motile properties. Some are heavy, some are soft, some are smooth, and others are rigid. The study aim of eliciting data on the experience of different motile qualities was addressed by presenting a variety of real world objects constituting different materials and thus, expectedly, different motile qualities. This allowed experimentation and validation of the research motivation (section 9) as I expected the participants to discern among the objects and report their different motile qualities. The objects included are listed in Table 3 and shown in Figure 9.

	Object	Properties
1.	A rectangular eraser	Blue in one end and white at the other.
2.	A small rectangular sponge	Cut from a blackboard sponge. Yellow.
3.	A space hopper	Multicoloured.
4.	A pipe cleaner	Squashed into a roundish form, Bright green.
5.	A chestnut	Brown.
6.	A metal pencil sharpener	Golden.
7.	A metal and plastic bicycle key	Black and silver.
8.	A metal ball	Green and patterned.
9.	A paper ball	White.
10.	A rubber ball	From inside a computer mouse. Dark grey.
11.	A tinfoil ball	Silver.

Table 3. The objects included in the participatory design sessions.

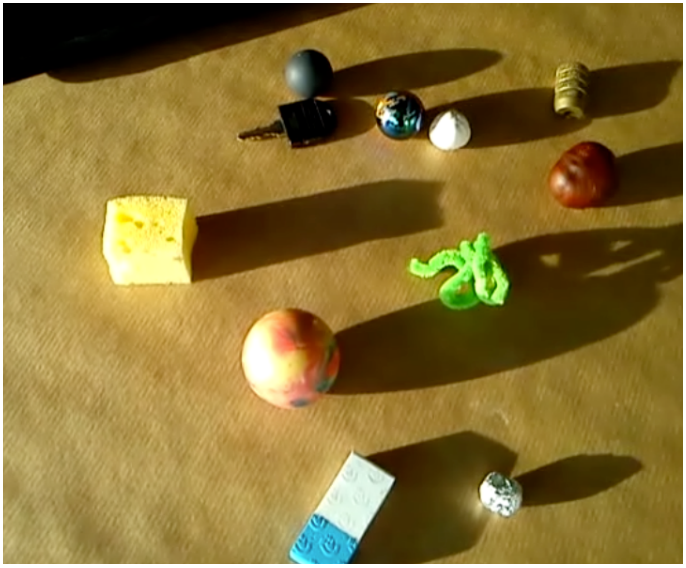


Figure 9. The objects included in the participatory design sessions.

The experimental setup meant to simulate the digital environment sketched by the mock-up (Figure 7) in an analogue, physical setting. The object properties, environment constraints, and user language, reactions, expectations and experience of performing the exercise in the physical world would serve as data for designing the digital version and the questionnaire. The analogue setup enabled investigation of the relation, composition and experiential effect of the exercise elements before coding into a digital version.

The sessions lasted between 20 and 40 minutes. The participants were initially instructed about the purpose and shown the interview guide. Consent to video record the session was also requested. The session then led into a discussion about the exercise and what made the participants aware of the motile qualities of the different objects. The digital mock-up shown in Figure 7 was also introduced to better explain the design idea. One challenge to the experimental setup was the 3-dimensionality of physical space. Participants had to be instructed not to *lift* the object onto the target area. Initially, this felt awkward, but the experimental purpose made participants accept this constraint.

Overall, then the sessions confirmed the motivation for the study exercise and brought out various decisions and requirements for the study design. Different movement patterns were involved: starting, stopping, pushing, flicking, changing direction. This led to discussions about the meaningfulness of the exercise and experimentation with obstacles to move the object around. Obstacles created situations that revealed different object affordances (Gibson, 1979). Like the difficulty in changing direction of a round object when pushing with one finger – it is very ”directional”, and reacts motionally when bumping into barriers. The shape of the objects influenced how participants moved them. Rectangular objects like the eraser and pencil sharpener tended to be oriented so that the shortest side was pointing in the direction of movement. Round objects did not produce considerations about orientation. Some participants stated preference about some objects based on their colour and motile qualities.

During the sessions, my understanding of requirements matured and patterns of agreement among the participants also emerged. One particular incident was central in understanding how to isolate movement from other stimulants like colour and context. During discussion about how to create focus on movement only, I improvised and asked the participant to close her eyes and then discern among the objects placed in her hands based on her ability to move them around in her hand (Figure 10). This implied use of only association to recognise or discern among objects. Only motion stimulated this association. No other perceptual stimulant was involved. Texture and shape were discerned via movement only and then associated to the objects used for the exercise. This was one of the moments of epiphany requested by Ellis et al. (2011). To create a focus on movement, then the exercise had to blank off other associative simulants like object colour, object shape, exercise environment, exercise task and physical context of exercise. Having different objects in each hand also showed that the element of comparison made possible the experience of difference among objects. The element of comparison would therefore be useful in the exercise.

Figure 10. "Blind-testing" during the participatory design session in my office.

The sessions also provided insights that helped decide device and whether to use landscape or portrait orientation. The participants preferred the landscape orientation, and they reported that the larger iPad display provided more space, and thus also time, for experiencing the movement and motile properties of the objects.

Discussions about the data collection method confirmed that a questionnaire survey would work for collecting data. It was also discussed to what extent the purpose of the study should be revealed to the respondents. This indicated *not* revealing the purpose to the respondents.

The participatory design method was very useful for creating an empirical foundation for the study design. The insights validated the methodological approach and refined the design requirements. Presenting the insecurities about the study design to potential respondents created openness towards non-academic guidance that was very valuable. The sessions also provided insights into how movement and motile qualities of objects are very important in human experience of the world. This validated the aim of researching the meaning making properties of digital objects in an interactive touchscreen setting.

The design session participants were later informed *not* to contribute to the actual study by downloading the App and completing the survey as they would be biased.

11.1.1 Design decisions and components

This section provides an overview of the decisions and components that informed the process of designing the study into its final incarnation as an iOS iPad App embedding a Google Form based questionnaire in two parts and a three course exercise for generating experience with motile digital objects.

11.1.1.1 Demographics and the app model

The App idea had matured before the participatory design sessions. Movement is experienced by all humans, so no demographic group was particularly relevant. Everyone was relevant. The ambition was therefore to generate a comprehensive sample across age and educational types. This ambition was supported by the app.-model for dissemination as it would make distribution seamless. The app distribution also allowed the respondents to control when and where to download the app and spend 20 minutes doing the questionnaire and performing the exercise. This again responded to the requirement for the exercise to be independent of the physical context (in perspective of the overall ambition of independence of context). Participation would be voluntary and physical circumstances would be controlled and possibly familiar to the respondents. The possible negative effects of having to travel and enter a formal test-setup were thereby minimised (Sonderegger & Sauer, 2009).

11.1.1.2 Demographics and qualitative methods

The demographics ambition, in terms of size and constellation, and the available ressources for data-collection, required a simple and efficient empirical method which would produce comparable data. The decision was therefore to design a questionnaire survey as this produces comparable data and a large sample would statistically validate the results. But of course not their correctness – a lot is not the same as reliable (Olsen, 2011). It was expected that most people are familiar with questionnaires, which supported the requirement for simplicity. To avoid coding and interpretation of respondents' statements then the questionnaire would only contain closed questions (Olsen, 2011). The participants in the participatory design sessions had not spoken against a questionnaire.

11.1.1.3 iPod vs iPad and Landscape vs. Portrait

The participatory design sessions recommended not using the Apple iPhone/iPod as the screen was too small for registering the motile properties. Also it would require versioning of the App. and thus straining the project ressources. The differences in screen sizes also constituted two different data-sets and therefore also two separate studies. Comparable of course. But a variety that was passed as scientifically not significant for the study purpose. Similarly for the screen orientation which development wise represented an increase in effort and design wise challenged the exercise as each orientation would require a different layout and thus also pointed towards two datasets. Therefore the iPad was selected and decision was to make the exercises in landscape orientation only. This latter decision challenged the questionnaire design where the ambition became not to have questions below the display edge (out of view).

11.1.1.4 Exercise components

The exercise was the central element of the study as it created the basis for the responses reported by respondents. The exercise consists of four components: 1) Objectives of exercise, 2) Object to move, 3) Task to perform, and 4) Environment in which to perform the task. Task, environment and object are reciprocal. This fragmented description therefore does not reflect the actual design process, but gives insight into the purpose and rationale for each component.

I refer to the respondents activities of contributing to the study by filling in the questionnaire and performing the exercise and submitting their answers as ”the test”.

Objectives

The objective is the design constraint controlling the three other components as it represents the scientific goal of the exercise (section 9): *To be able to evaluate the experience of motion independently of any other contextual factors.* Four perspectives describe the objective:

1a. Secure focus on movement by neutralising context: The expressive emphasis had to be on movement to prevent other associative stimulants from creating the respondents experience: Neutralising context in the sense of physical setting was addressed by the App.-model. Context in an interactive digital system sense was addressed by neutralising the associative power (semantics) of the three other components (object, environment, task). The neutralisation also meant to reduce the iPad hype effects (socio-cultural context) and the technological setting in general.

1b. Comparability: The respondents had to report experience of more than one motile object because it was not possible to register any valid experience of motion by only presenting one object exhibiting one motional pattern. Presenting several different motional patterns would generate data on respondents’ ability to discern among, and recognise visually identical objects based only on motion. These cognitive performances would support the hypothesis about motions ability to instill meaning. Reporting positive motional experience of only one object (yes, it has motile characteristics) could be a lucky guess. But reporting different motional experiences among several visually identical objects (Yes, I see three different objects) could not be coincidental. In particular not if the group of respondents was large enough for statistically valid patterns in responses to form. A formation of agreeing patterns in identification (by association) among respondents would also indicate culturally common semantics for certain motional patterns.

1c. Respondents: The study did not concern a particular group of users as all humans are conditioned to react to movement and understand this phenomenon. The study aim of creating a foundation for studies into contextual application of movement meant that the study could not exclude anyone. Contextual studies would then be able to research different user groups on this generic foundation.

1d. Simplicity: The exercise had to be simple as the respondents included everyone. Respondents at either end of the scales of age and technology experience should be able to contribute without any assistance. This had two reasons: One was to allow as many as possible to contribute as mentioned in item 1c. The other was the distribution model which required the study to perform without any breakdowns in usability that would take the focus off the respondents’ completion of the test.

Object

The objects represented motion in the exercise. The experience of motion is possible via both visual, auditory and somatosensory stimulants. Only the visual parameter was relevant for this study. As required by objective 1b (comparability) then it was decided to include 5 objects in the exercise. These objects had to be visually neutral in regards to colour and shape and not discernable by these parameters, only by motile differences (objective 1a, movement focus). Meaning: All 5 objects should look the same, but exhibit different motile patterns.

A *motile pattern* was defined as *movement of* the object and *inert movement*. These concepts were defined specifically for this project and a further explanation is provided in section 19.1 and 19.2. *Movement of* is the ability of the object to move from one point to another. In the exercise this object property (or affordance) was controlled by the user being in contact with the object via his/her finger. *Inert movement* is the motile properties of the object exhibited when interacted with. This will typically be deformations and graphic changes (feedbacks that reveal affordances). The motile properties, constituting the specific motile pattern will be exposed when the object is manipulated (via gestures or system events) and/or brought into contact with elements in and of the environment. *Movement of* and *inert movement* correspond to the two basic *spatial qualities* of movement defined by Maxine Sheets-Johnstone (2011): *Linear* (line of movement) and *Amplitudinal* (areal extension of movement).

The selected 5 motile patterns were inspired by experience with different objects in the participatory design sessions (Table 3). A *motile pattern* is created from a combination of movement of and inert movement. Objects with different motile patterns will exhibit different behaviours when activated by user or system. The difference in patterns is dependent on the two *temporal qualities* of movement defined by Sheets-Johnstone (2010, 2011): *Tensional* (effort) and *Projectional* (character) will add expressive difference in the patterns. Inert movement also covers the temporal qualities. The division into these four qualities by Sheets-Johnstone is formal, as they are always all present in any movement. But the division is useful for creative and descriptive purposes. A further discussion of movement is provided in Part III.

The materials that the 5 objects should mimic were: 1) Rubber, 2) Metal, 3) Paper, 4) Sponge and 5) Neutral. The latter being an object with no inert movement, only movement of. This was to have an object which in principle had no motile pattern. This object was included because the identification by respondents of ”no inert properties” would *also* signify the ability of movement to instill meaning. The lack of inert movement, only being movable, is also a motile quality and this object would therefore represent a baseline for identification of motile differences because it exhibited a motile minimum. The 5 different objects supported objective 1b (comparability). The materials were selected as they by general skills and awareness of naîve physics (Jacob, Girouard, Hirshfield, Horn, Shaer, Solovey & Zigelbaum, 2008) and the participatory design sessions, exhibited different motile charcteristics and thus supported objectives 1a (movement focus) and 1b (comparability). The challenge was how to transfer these characteristics to a digital incarnation. Tackling the animation effort is described in section 11.1.2.

It was decided to make the object(s) round and a light grey colour was selected. Both of these decision were made to neutralise the associative power required by objective 1a (movement focus) and to support objective 1d (simplicity). The grey colour was in concordance with the overall colour scheme decided for the environment.

Referencing the round object in the questionnaire represented quite a challenge to objective 1a (movement focus) as any term would include some semantic reference and thus associative value. ”Object” was too abstract and ”Ball” was very much too indicative. ”Ring” was not correct as the object had fill-colour and no outer ring. Eventually ”Circle” was selected as this was semantically correct as the object is a circle and the word has no immediate associations to any common tasks. This decision was also influenced by the questionnaire design activities (section 11.4).

Only simple one-touch gestures were supported for interaction. No multi touch. Gestures were: Press, Release, Press and hold, Drag and Flick. Drag, of course required Press and hold to be performed first (Saffer, 2009).

Task

The task presented the purpose for the respondent to interact with the object. The task had to support objectives 1a-d.

Objective 1d (simplicity) was supported by maintaining the task already present in the initial mock-up (Figure 7): Move an object from position A to position B. It was expected that everyone in the respondents group would be capable of understanding and performing this task. This had been confirmed by the participatory design sessions and the task was therefore expected to achieve objective 1b (respondents). This was later confirmed as no-one reported difficulty in completion when the iOS App was released and 90% of respondents reported the exercise as not difficult (section 12.21). Nor was difficulty observed when the study was presented to 24 kindergarten kids or among the 11 people reporting no touchscreen experience.

Moving object position is a very simple task and stood out as meaningless. If the task was meaningless, then the whole study would appear meaningless and thus possibly create a negative approach to the test. The experimental setup (Figure 8) had proposed a little complexity to the task by introducing an obstacle to the environment (a straightened paper-clip) to force movement of the object into arbitrary linear movement to better experience the motile properties (objective 1a). This obstacle also added meaning to the task, as the navigation towards target position now required the respondent to explore by negotiating the environment with the object.

This minimal meaning also supported neutralisation of context (objective 1a) as this task was not immediately associative to any user interface context. Of course this effect was a result of the reciprocal relationship between task, object and environment. Reciprocal in the sense that the experience of the task is also dependent on these other elements. The task could not be performed without object and environment and the experience of the task is therefore also a result of these elements. The task is in principle analogue to moving a folder or file icon across the desktop, or repositioning iOS App icons, but the environments and graphic expression neutralised this association.

Objective 1b (comparability) was supported by repeating the task (move object to position), for all three courses described in next section.

The task also addressed the methodological purpose of concealing the scientific focus on motion to prevent skewed responses. At least while performing the exercises. The survey questions would probably give the focus away gradually. This presented a challenge addressed by the questionnaire design (section 11.4).

Environment

The environments were designed to present neutral, non-associative contexts and to create variation and support comparability in repeating the task (objective 1b). Three ”courses” were designed to experience the 5 objects under different circumstances, and thus support objective 1a (movement focus). The three courses were respectively a ”labyrinth” (Figure 11), an open space (Figure 12), and an obstacle course (Figure 13). The courses were presented to the respondents in that sequence.

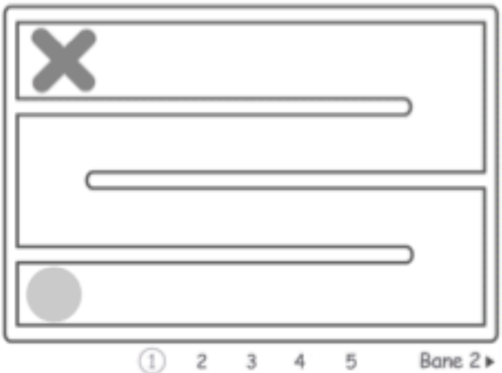


Figure 11. The labyrinth course was presented as the first course to complete.

The labyrinth course required the respondents to move the object through a narrow and winding path. The three bends provided opportunity for experiencing the inert motile properties of the object. Some data collection sessions (section 11.5) made it possible to observe respondents perform the task and the labyrinth course was popular among some respondents as they tried to negotiate the path without bumping into the sides. This was hard and they reported some of the objects to be lively. Thus the course had the intended effect of creating experience of the motile patterns. It was also interesting to observe how the respondents added an extra parameter to the basic move task.

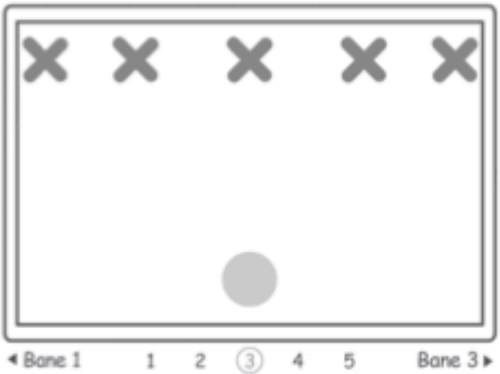


Figure 12. The open space course was presented as the second course to complete.

The open space course was designed to provide an area for playing around and exploring the object properties. Five X'es were present and when the object went over an X, then the X would disappear. The intention was to inspire the respondents to flick the object toward the X'es as this would reveal motional properties. I did not observe this behaviour in any respondents as they tended to follow the instruction: Move circle to X. The many X'es however, did inspire some respondents to add efficiency as a parameter and therefore removed all five X'es in a single swiping movement of the circle. When selecting a new circle, then the five X'es would reappear.

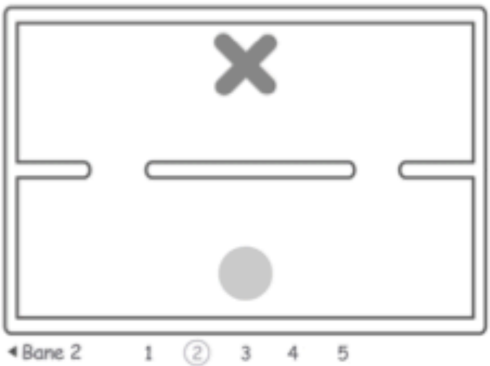


Figure 13. The obstacle course was presented as the third and last course to complete.

The obstacle course was inspired by the simple obstacle variant invented during the participatory design sessions as it presented a horisontal barrier with two openings. The right opening was exactly too small for the object to pass through – even for the most deformative variant. The left opening was wide enough for the object to pass through. As with the labyrinth course, then the intent was to force respondents into getting to know the circles inert motile qualities by forcing this negotiation of a narrow opening. Most respondents quickly found out that the left opening was the ”fast route to completion” and thus choose this route towards the X.

Among the three courses, then the labyrinth course appeard to be the most fun and meaningful. This observation underlined the value of three different courses. Only one course could not have provided the same base of experience to the respondents.

All three courses were designed to adhere to objective 1d (simplicity) in graphic appearance. The colour scheme was three levels of toned down grey: one for the ”X” indicating target area, one for the object fill colour and one for the lines indicating course edges and obstacles. The shapes used rounded corners and no fill inside the obstacle elements to signify openness and create an inviting appearance.

The complexity of the environments in terms of number of obstacles and different element shapes was kept to a minimum to support objective 1d (simplicity). But still representing a small challenge so that the task appeared meaningful.

A common denominator among the courses was the ”X” representing target position and the start position of the ”Circle”. The ”X” was chosen to represent target position as a cross is a culturally common symbol for signifying a target location. The circle start position was aligned at the center along the lower part of the courses.

A ”navigation bar” was located below and outside the course-area to enable navigation between the courses and to select which circle to move. Navigation between courses was done by pressing the text+arrow element in either right or left side of the nav.-bar. The numbers 1, 2, 3, 4 and 5, were presented in the middle of the nav.-bar for the respondent to select which object to move. The number corresponding to the currently selected object was dimmed. No functional animation was added to neither the elements of the nav.-bar nor the shift between courses.

In the labyrinth and obstacle courses, the object would automatically ”lock and center on the X”, when the object had 50% coverage of the X. This behaviour was implemented to signify completion of task. It was possible to move the object away from the X after the ”lock” event. Selecting a new object removed the current object from the X and presented a new (but visually similar) object at the start position and dimmed the currently selected object number in the nav.-bar. The respondent could try the same object as many times as desired. There was no limit on the number of ”attempts”. No internal system secured that all circles were actually tried. Such restraints were not implemented to prevent a locked situation that created frustration of not being able to explore the objects. This open approach also governed the decision to allow respondents to return to the exercise during part 2 of the questionnaire. This was implemented to prevent the study from being a memory-test as some of the questions concerned details of the motile properties that might make some respondents wish to revisit the exercise to confirm their recollection.

To secure correct performance of the task, the respondents were instructed at the end of the questionnaire part 1 (section 11.2) about the task, the three courses, how to navigate between courses and that they should complete each course five times by pressing 1, 2, 3, 4 and 5. The precise instructions are found in Appendix A

The course designs may, to some respondents have presented the exercise as a game. But the simplicity of the task, and the lack of any game mechanics were also meant not to support this impression. The respondents had total control of the exercise progress and were allowed to navigate forth and back between the courses. The repetitive fashion (perform the same task 5 times for each course) and the overall setting within a questionnaire survey connoted test rather than game.

Result & Effect

The result of supporting objectives 1a-1d was 5 visually identical, but motionally different objects to utilise by the respondents to successively complete a slightly meaningful task within three stylistically similar, yet different environments.

The study presented an experience oriented exercise that did not ask or require the respondents to perform by certain parameters of efficiency, effectiveness, or play. The exercise was very open ended. The scientific focus on movement was not apparent and the exercise possesed no graphic, symbolic or functional components that associated to any well-known interactive digital system functionality or purpose.

The exercise allowed respondents to gain varied experience with the motile properties of the 5 objects within a reasonable timespan. The exercise fulfilled all objectives and was therefore assessed as properly useful for collecting data to inform the research question and hypothesis. This was confirmed during the questionnaire pretests (section 11.4.1).

11.1.2 Animation of ”the circle”

This section presents the activities that produced the motile pattern of the five objects. The motile patterns were of course designed by an animation studio. The startup Tumblehead[13] from Viborg was selected as partner for this endeavour. Tumblehead also conceptualised the complete graphic profile and all graphic elements of the exercise and nav.-bar components.

The initial contact between Tumblehead and me was a briefing about the study purpose and requirements for the objects and environments. Proposals for the material models for the five objects were presented and likewise the basic ideas for environments. Tumblehead then provided mock-ups that provided opportunities for

[13] Tumblehead.com

experiencing and evaluating the ideas in an iterative process. Most evaluations were heuristic against the objectives of the exercise and purpose of the study and served to refine the number of courses, their design, and of course the motile qualities of the objects.

In February 2012 a questionnaire based evaluation of the five objects was performed in cooperation with 18 students (primarily) and teachers at The Animation Workshop in Viborg. The purpose was to have trained animators evaluate Tumbleheads proposed digital 2D emulations of motile patterns for metal, sponge, rubber, paper and neutral. The aim was to provide peer feedback for Tumblehead so that the final objects did not constititute Tumbleheads idiosyncratic understanding of the five materials. The peer-review should establish a foundation for the motional element of the study design that reflected a both professional, but also culturally broad understanding of the materials. This would make the design reflect broadness in origin similar to the broadness desired in the group of respondents.

The TAW animators were briefed about the purpose of the study and the objects. A server provided access to five Adobe Flash movies presenting non-interactive versions of the objects (Figure 14). For evaluation of the animation properties it was considered not relevant for the mock-ups to be interactive. The flash movies all presented the same environment. An on-line survey collected written quantitative and qualitative evaluations and comments[14].

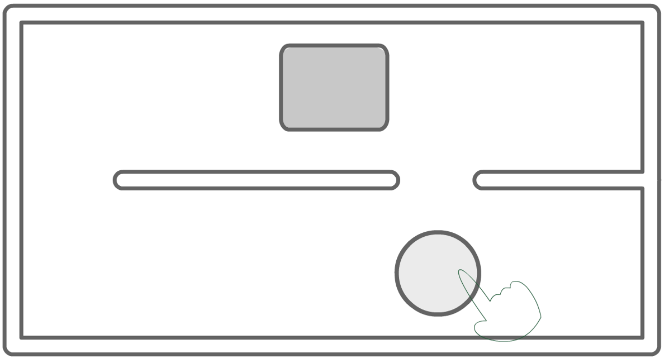


Figure 14. Image from one of the Adobe Flash movies presenting Tumbleheads effort at emulating rubber, metal, paper, sponge and neutral.

The questionnaire requested demographic data, information on animation experience and also asked the respondents to report their immediate impression of the objects. This aspect served as a pretest of how to ask about the study hypothesis. All 18 respondents reported noticing the difference between the neutral and the four other versions. 13 reported the five versions as *different* and 5 reported that *some are very similar*.

[14] available upon request to mlund@hum.aau.dk

The questionnaire then asked the respondents to report their evaluation of how well the mock-ups emulated the five materials. The result are presented in Table 4.

This evaluation led to a request for a quantitative proposal for changes (5 point scale) of the motile parametes in relation to the gestural interactions depicted (drag, release, flick, etc.) via the 12 animation principles (Thomas & Johnston, 1984). These questions related to the gestures as each gesture caused revelation of possible inert motile properties.

Question: Does the animation, to you, provide the impression of "material" ?

Object	Yes		No		Total	
Metal	8	44%	10	56%	18	100%
Paper	3	17%	15	83%	18	100%
Rubber	10	56%	8	44%	18	100%
Sponge	9	50%	9	50%	18	100%
Neutral	17	94%	1	6%	18	100%

Table 4. Overview of responses of TAW animation students when asked about the objects' emulation of the five motion patterns.

As is apparent fromTable 4, the respondents did not agree. For both metal, rubber and sponge the responses showed absolute disagreement as precisely 50% on average thought the Tumblehead objects did resemble the materials intended, whereas precisely 50% on average thought they did not. The paper animation got positive peer evaluations and so did the neutral version. The comments for the neutral version confirmed the distinction between *movement of* an *inert movement*. This was apparent from respondent answers like: "*Because the only movement seen is that inflicted by the user dragging the object. The object does absolutely nothing!*" and "*The only movement is performed by user*". The students saw the object as motile, but without any properties providing material character.

The quantitative feedback, concerning the 12 animation principles (Thomas & Johnston, 1984) for each action type, was too complex and difficult for Tumblehead to transform into viable changes. Also, as apparent fromTable 4, the disagreement among respondents established conflicting recommendations which were imposible to integrate into one object. The qualitative feedback however, was useful in the following iterations. The results from the TAW student evaluation are not in appendix, but will be provided upon request.

The disagreement among the animators was of course problematic from the perspective of countering Tumbleheads idiosyncratic design. But this disagreement also supported the rationale for the study. I had observed differences in motile patterns and difference in the contexts where movement was applied and decided not to use these specific designs as basis for establishing functional animation. The respondents' disagreement showed that specific design products will always be a result of multiple factors. When asked about the properties of some phenomena – e.g. movement and reaction of a metal object - you get 19 different answers (18 TAW + Tumblehead). My notion, that investigating existing designs would only provide data on these particular concepts and not (necessarily) reveal any generic knowledge, was confirmed and substantiated. This again provided a basis for Tumblehead to continue their idiosyncratic work.

These considerations also explain why the questions in the questionnaire are about *discerning* among objects, not *recognising* objects as representing something. The questionnaire does ask whether respondents associate the objects to the materials emulated, but the purpose is not so see whether respondents recognise what it is supposed to mimic. This is just one of many possible versions of an animated ”metal object” in a digital touch setting. The 18 other animators would do it differently. The purpose is to see if the object creates associations at all, based solely on the motile qualities. Surely it would be recognised as metal if provided with a silvery graphic and rounding shadows, and maybe a clanking sound. The questionnaire also asks about associations to characteristics like kind, annoying, lively, etc. to not only elicit responses on the inspiration used for the objects (materials), but also the affective dimension of the objects.

To finalise the object animations a common session between the Tumblehead animator, Peter Smith, the iOS App. developer, Morten Bøgh and myself, who had multiple roles as both designer, researcher and customer, was conducted in October 2012.

The animation of the final objects ended up being less of an animation exercise as the software used for constructing the motile patterns fell into the category of ”computer controlled animation” and not ”computer aided animation”. Within both approaches all creative and generative processes take place within a digital system. *Computer aided animation* is when a digital system assists the animator in creating the frames interpolating between keyframes. The keyframes along the animation timeline, object properties like position, size, rotation, colour, etc. and timing between keyframes are defined by the animator. The complete sequence of interpolating frames is then generated and the animator has ”final cut” in manipulating the now complete set of frames. *Computer controlled animation* has a range of different approaches, but is characterised by the computer system being in control of the unfolding of motion. Animation is exercised by the programmed object, the environment properties and object relations (Thomas, 1998).

The sw tool brought the object motion design into the realm of computer controlled animation as the sw tool defined the parameters available for defining the motile patterns. The final objects therefore ended up being as much emulations of specific materials as they were expressions of arbitrarily different motile patterns. Two strategies were employed to design the motile patterns: One was designing toward the material profile in question independently of the other objects. The other was a comparative approach that served to secure difference among the objects without caricaturing the motile patterns. Table 5 list the programming values that defined, and set the objects apart.

		Object value				
Action	**Object Response**	**Neutral**	**Metal**	**Rubber**	**Paper**	**Sponge**
Press	Deformation	-	-	10	50	70
Release	Regain shape	-	-	-	-	-
Drag	Deformation	-	-	-	70	50
Travel	Deformation	-	-	-	60	40
Impact	Deformation	-	-	20	90	70
Impact while hold	Deformation	-	-	-	90	70
Flick	Result of mass and friction: how far does object travel	-	90	90	20	30
Bounce on impact	Loss of acceleration over time (decelleration) Low number = fast decelleration	-	30	70	10	20
Fingerglue	Object follows path of finger. Even if no ”contact”.	100	100	100	100	100

Table 5. Overview of the values ascribed to the various actions available for the 5 objects. The values are from the implementation tool, Cocoa Toch.

The animator functioned as ”motion supervisor” in this final design session. In cooperation we settled the motile patterns into the form implemented in the iOS App. We assigned the descriptions listed inTable 6 to the objects.Table 5 is the system values formalising these semantics.

Object	**Description**
Metal	Heavy and hard
Rubber	Hard, but forgiving
Paper	Light and fragile
Sponge	Airy, but with structure
Neutral	Dead

Table 6. Description of the final motile patterns for the 5 objects.

11.2 iOS App design

The iOS App provided the technological foundation for both exercise and questionnaire and enabled an integration hereof into one ”package”. Some of the advantages of the App model have already been mentioned. The requirements for the App was 1) Enable access to the exercise, 2) Enable reporting of the experience of motion and 3) Enable anybody to do item 1 and 2 without assistance.

Access to the exercise equaled the iOS App itself as the exercise technologically *is* an App. The challenge was to provide access to *both* exercise and questionnaire within the frames of an App-environment while fulfilling requirement no. 3. This turned the study design into also being a sw development project.

From the perspective of data collection, I wanted to separate the collection of demographic data from the collection of exercise data. The reporting of movement experience had to happen immediately after completing the exercise. The concern was, that if the exercise was performed first and followed by demographic questions, then the respondents would not be reporting their immediate experience of the exercise, but their recollection and rationalised version hereof. In hindsight, then I could have located the demographic questions at the end of the questionnaire. However, the structure illustrated by Figure 15, possibly also had the advantage of making the respondents' experience of contributing less dominated by the questionnaire element as this was now interrupted by the exercise.

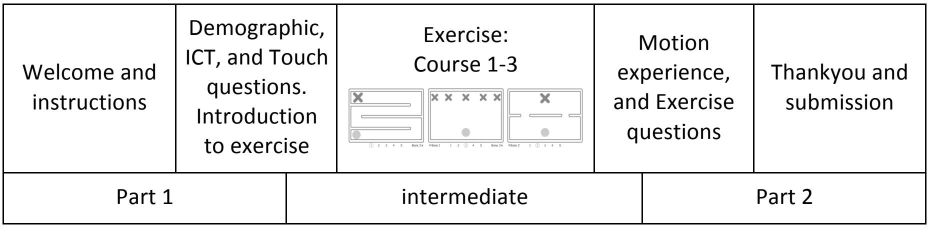


Figure 15. Model of the iOS App structure.

This structure presented a slight challenge of information architecture and navigation design. In particular as the sw development framework had to abort the Google form used for the questionnaire at the end of part 1 (page 9) and pick it up again at stage 2 (page 10).

To respond to a concern about the reporting in part 2 becoming an exercise of recollection, then the app.-structure also had to allow navigation back to the exercise while completing part 2 of the questionnaire. This feature allowed respondents to explore and get to know ”the interface” represented by the exercise. All user interfaces have a learning curve that require the user to perform similar tasks multiple times to go from recall to recognition. Tokárová and Weideman (2013) mention three general phases which they apply to a study of learning mobile toruchscreen interfaces. Allowing users to return to the exercise therefore supported a natural process of familiarisation. Of course the 5x3 performances of the task did familiarise the respondents with the task and environments. But in reality, then they only experienced each object three times, and each time under different circumstances (new course).

However once the structure and navigation was agreed and found technically feasible, then exercise design activities represented the dominant part of realising the iOS App. The questionnaire design was independent of the App design. The only connection between the two were some invisible markers embedded into the Google Form that enabled the break between part 1 and part 2.

The App. contained one important element which addressed the validity of the data collection. The sequence of the objects presented to the respondents could not be the same for every activation of the App. The sequence itself could make up an associative stimulant to the respondents if the objects somehow composed a narrative or other sequential meaning. The App. therefore shuffled the sequence of the objects every time the App was initiated on the iPad. The sequence of objects was therefore randomised for every individual respondent, also if they used the same iPad.

The programs used for creating the app were Cocoa Touch og Cocos 2D and the result was an iOS app, approved by Apple, and available via the Apple Appstore for anybody to download.

The integrative approach described probably constitutes a methodological novelty. But I have not investigated this aspect.

11.3 An abstract system model

The previous sections describe how the individual components came to constitute the exercise. To put the exercise design into a theoretical perspective on interaction design I introduce a model (Figure 16) presented by Tom Hede Markussen in 1995 (Markussen, 1995). The model is by Markussens reference based on Preece (1993) and presents the four factors, or elements, that affect the design of an interactive digital system: *user*, *task*, *tool* and *context*. Each of these represents complexities in their own right, but in interaction design they come together and condition the fifth element: *experience/interaction*. Markussen (1995) uses the Danish word ”betjening” for this fifth element which translates into ”operation”. Going back to the source, then Preece (1993) says: ”Each of these four components has its own characteristics, all of which influence the nature of the interaction between the user and the computer system …” (Preece, 1993, p.12). Preece thus uses the word *interaction* and not *operation*.

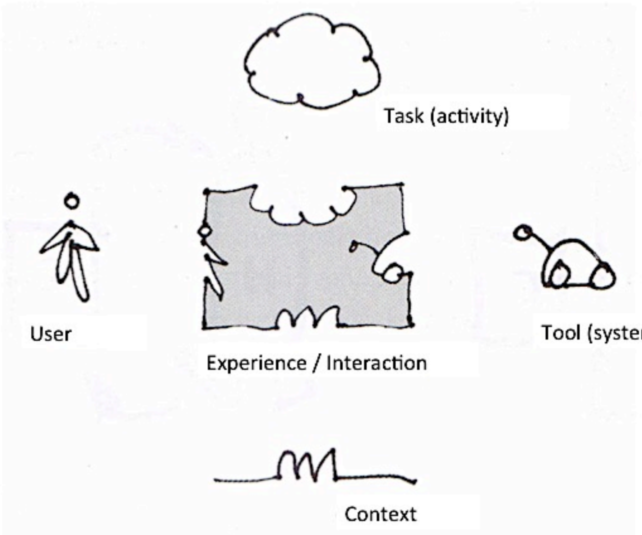


Figure 16. The four elementary components of experience / interactivity.
Illustration by Markussen (1995). ML translation of terms.

Jensen (2013) illustrates how understandings of the dynamics between the four elements have developed into the broader view of, not only system interactivity, but facilitates the total ”user experience”. Jensen (2013) presents a diagram based on the definition of user experience in ISO 9241-210:2010[15]. This diagram includes user, system and context, but the *task* element is not explicit in these two references and thus the diagram. It is implicitly part of them as there would be no *use* without a goal and interactions to achieve this goal. An aspect underlined by Cooper, Reimann and Cronin (2007), who name their design process ”The Goal-Directed Design Process” in accordance to their focus on enabling a user to achieve a goal via designing supportive system interactions. Task is probably omitted in Jensens account (Jensen, 2013) to allow the diagram to explain instances of both productive and recreational systems, which by their nature will have different goals and thus require types of tasks that are difficult to explain by the same parameters. However, Jensen (2013) does explain how it is possible to design *for* an experience by shaping the product (tool/system) to ”… trigger certain interactions with the user … and thus create a certain experience … without guarantee” (Jensen, 2013, p.31-32). This account describe how the experience is dependent on the users interactions with the system (tool) which again must be the result of the users experiential or(and) functional goal for initiating contact with the system. I will therefore maintain task

[15] entitled: ”Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems”. http://www.iso.org/iso/catalogue_detail.htm?csnumber=52075 (accessed October 2016).

an important and independent element, but also recognise how the effect of the four factors is not only *operation* or *interaction* as explained by Preece (1993) and Markussen (1995), but also *experience*. Markussen concludes his account by a disussion about product quality: ”In relation to the users total experience of a product (tool, ML), the operation (interaction, ML) appears to be an important parameter” (Markussen, 1995, p.59)[16]. Thus Markussen foretell the extended focus in interaction design and kindered disciplines on user experience.

User is the person using the system. The user has a physical and a mental dimension. No users are uniformly alike and their appraoch to the system will therefore be different, but yet overlapping as they do share common human and intentional traits in their approach to the system. Understading users and user requirements is important in interaction design and may include perspectives like ergonomics, perception, cognition, behaviour, learning, semiotics, communication and social dynamics.

Context is by Markussen (1995) the physical surroundings of the system. The context will have both a physical and a mental effect on the users appraoch to the digital system. Physical context is particularly relevant to mobile technologies as such devices allow usage under, in principle, any conditions. I will add the digital surroundings to the concept of context as a digital system in many cases also exist in correlation to other digital systems on the same device or technical platform. These digital surroundings effect the handling and approach to the system currently in use. Or more correctly: systems, in plural, as many platforms allow multiple simultaneous processes and exchange of content among these. Complex operating systems like Microsoft Windows and Apple iOS and OSX represent such digital system contexts which affect how individual systems and system relations are understood.

Tool is the digital system itself. This concept covers the technical implementation of features as well as the user interface that allow the user to access and operate these features (interaction). Markussen (1995) uses the term ”product” which is more abstract as it does not imply a functional purpose, and covers systems that are not aimed at productivity. Preece (1993) uses the term *system*. I have chosen the term *tool* as it covers the description of *product* provided by Markussen (1995, p.32). Tool is therefore functionality in the broadest sense as it represents a digital system that allow the user to perform activities towards achieving both productive and recreational goals – as indicated by the description above by Jensen (2013). The characterisation of the tool depends on the users intend, capabilities and system features (what actions it allows). An example could be a spreadsheet which allow the accountant to do bookkeeping, the project manager to maintain a backlog or do a schedule, and the kid to do a picture via colouring the individual cells. The nature of the goal and perception of the tool affect one another. The kids sees the system as a

[16] My translation. Original text: ”I relation til brugerens totale oplevelse af et produkt, synes betjening at være et væsentligt parrameter”.

tool for drawing and achieving a primarily experiential goal whereas the accountant and project manager have primarily productive goals. However, all three users will evaluate the system based on parameters of both usability and experience of achieving the goal via the system – the user experience. Jensen (2013) discuss the relation between usability and user experience and conclude that the two phenomena are different as experience is subjective in its origin with the user wheras usability is objective as it relates to the system. But ”perceived usability” is a subjective factor within the users overall experience. The tool is therefore both a vehicle for practical and emotional satisfaction, or not.

Task is the activity to perform. It may be consituted by several sub-tasks, but will eventually result in achieving a goal. The goal may be functional and/or experiential. The term ”task” connotes productivity and is anchored in the historic origins of viewing interactive digital systems as tools for work related tasks (Preece, 1993). *Task* may therefore also be referred to as *activity* in order not to exclude activites with a primarily experiential goal. Markussen (1995) define two dimensions of the taskelement: One is the overall *goal* that the user wish to achieve by using the system. The other is the *operations* that the user performs when interacting with the system features via the user interface elements. Operations are performed in order to achieve the goal. This dimensionality of the task element introduce a conceptual separation between interaction and experience which is also found in Hassenzahl (n.d.).

Hassenzahl (n.d.) suggest three levels when designing (for) an experience through an interactive digital system: *Why*, *What* and *How*. He explains the levels as follows: ””’

> ”The *What* addresses the things people can do through an interactive product … Reflected by a products' functionality, the What is often intimately tied to the technology itself or a certain product genre. The *How* in turn addresses acting through an object on an operational, sensory-motor level: Buttons pressed, knobs turned, menus navigated, touch screens stroked, or remotes waggled. … Nowadays, the bundle of What and How is typically considered the product, and an especially sensual, aesthetic, novel, or stimulating arrangement of interaction makes this product ’experiential’. This view ignores peoples' actual motivation to use a product. For the couple being separated, the SMS was not primarily an SMS, it was a love message, a way to fulfil their need for relatedness. This is the *Why* of product use. … The telephone just happens to be instrumental, but it does not necessarily reflect upon the underlying needs, emotions, and associated practices” (Hassenzahl, n.d.)

Hassenzal (n.d.) suggest the design process to start with the *Why* by understanding the needs and emotions motivating an activity. These would be the experiential goals of the activity supported by the system. Next step is looking at functionality in terms of *What* features to include to support the goal. This level opens up the grey zone between experience and functional performance (as discussed in relation to usability) which by designing the *How* specifically address the interactive elements of the system. In a comment to Hassenzahls text Paul Hekkert propose changing the order of *What* and *How* as the *How* ”… captures the way people will interact with and experience the to-be-designed product that is not yet defined” (Hekkert via Hassenzahl, n.d., p?). In relation to Markussen (1995) and my arguments for the task element, then these views by respectively Hassenzahl and Hekkert support the presence of interactive elements with a functional character also when focused on designing for the experience. The experience is the goal of the interactions and there will be no experience without the functional interactions. Now, the user may not know that their goal is affective, theyre just calling their friend, but when the call is disturbed by hardship in adjusting volume or mute buttons being pressed accidentally, then the system interactions do affect the experience of the achieved goal.

The functional interactions will always be present, but may be a well integrated part or so mediocre to the overall product performance and thus the product experience that the user is never attentive to the presence of these operations. ”Form over function is often the path of mature products” as Nicholas Negroponte said in 1996[17] when predicting how technology would slide to the background in how users approach activities in the digital realm.

Functional animation is part of the interactive and experiential dynamic within the discussed model, albeit a easily overlooked component. But the model is also a model of the exercise designed for the study. The following example illustrates how:

A girl is walking down the street with a bag in her hand and takes out her phone to call a taxi. This describes the *user* as one handed, and in motion, thus having her attention distributed across at least two *tasks*: Navigating physical terrain and the phone interface. The *context* is the street and the weather (maybe it rains, or sun is bright), but it is also the environment of the phone interface. The phone application is the *tool* for achieving the goal of the ”call taxi” *task*. Her *experience* is the emotions resulting from the interplay of the four elements.

The same girl is walking down the street with the bag over her shoulder and takes out her iPad to move a circle to an X. This describes the *user* as one handed, and in motion, and her attention distributed across at least two *tasks*: Navigating physical terrain and the iPad interface. The *context* is the street and the weather (doesn’t rain), but it is also the environment of the iPad interface. The circle is the *tool* for achieving the goal of the ”move circle to X” *task*.

The exercise constitutes an interactive digital system and the example illustrates how the exercise is an abstract model of the four elements because it de-contextualises user, context, task and tool. The example also illustrates how the exercise only has real meaning in the context of this research project. In this research context the exercise is an abstract system model dedicated to exploring

[17] www.wired.com/1996/12/negroponte-44/ (accessed October 2016).

whether movement has any influence on the fifth element: *experience* of movement in an interactive digital touchscreen system.

The real functional value of the exercise is the generation of data for exploring the phenomenon functional animation. From a research perspective (researcher as *user*), then this generation of data is the *task* enabled by the *tool* (the exercise). The research project is the *context*.

Because the study is based on this abstract model (decontextualised content) and not a specific study of existing devices or specific motile patterns in relation to specific use scenarios then the study will provide a foundation for research into exactly that dimension of functional animation: specific motile patterns in relation to specific use scenarios. This study provides an empiric and abstracted basis for these studies of specific usages.

11.4 Questionnaire design

This section describes how the questionnaire was designed. The exact questions and motivations will be presented in section 12 where the results are also presented.

The motivation for collecting data via a questionnaire survey and only presenting closed questions is stated in section 11.1.1.2. The quantitative survey approach is discussed in section 8

The questionnaire design was based on Boolsen (2008) and Olsen (2011). Not only theory informed the design, as recommended by the literature, pretests were also conducted.

11.4.1 Questionnaire pretests

A challenge in designing questionnaires is the very finite form. When released, then the results are what the questions ask, or rather: what the respondents understand by the questions. Being precise, brief and unambiguous is key to a successful questionnaire. But first of all the questionnaire designer must know what he/she wants to know. Which questions will answer the research hypothesis?

The questionnaire design was, like the exercise design, an iterative process. The two processes were synchronized as considerations about how and what to ask informed the requirements and iterations of the exercise. The questionnaire was like the exercise evaluated in the company of colleagues, but two structured test were conducted when interactive exercise mock-ups were available for the iPad.

The first pretests were performed at the entrance hall of a swimming bath/library as this public place allowed access to a broad selection of possible respondents. Instead of selecting, contacting and setting up a test-session, then this approach allowed immediate contact to whoever came in and looked vacant. This also had the advantage of randomizing the selection of test-subjects. I had the privilege of a research assistant who took notes while I guided the respondents through the questionnaire (on paper) and the exercise mock-up. No video or audio recorder was used for documenting these sessions as the notes were sufficient for maintaining the feedback provided by respondents. This approach created three sessions which uniformly showed that the current version was too long, and too complex. We had estimated 20 minutes and one session took over an hour. This helped focus the questions as it had to be possible to complete the study in 20 minutes or less. If longer then respondents would feel overwhelmed and loose interest in proper reporting. That we learned from the pretests.

The questionnaire was iterated and a new evaluation was set up. This time a structured session with a married couple in their 60'ies that were friends of mine. Both of them retired medical doctors. These were long sessions. But the intimacy of the sessions and the willingnss from the respondents to make the questionnaire work as intended provided much valuable feedback. This evaluation created the basis for the iterations that produced the final version of the questionnaire.

11.4.2 Question categories

The questionnaire was split into two parts, as illustrated by Figure 15. Part 1 had 8 questions that addressed demography and respondents' relationship to information technology in general and touchscreen interaction in particular. Part 2 had 13 questions that addressed respondents' experience of the "circles", the factors creating this experience and the respondents' experience of the task and task environment. Most questions included sub-questions that required the respondent to select a value on a scale. The following question categories constituted the questionnaire:

Part 1, Demographic data
Questions 1 & 2. Age, gender and educational background are standard demographical data and provide an overview of the composition of the respondents group. This was useful for evaluating the representativity of the respondents group.

Part 1, ICT experience, attitude and preferences
Questions 3 - 5. These questions provided general insight into the respondents' approach to information technology. This was to be able to evaluate whether the answers for the study hypothesis were influenced by tendencies in the respondents' approach to ICT.

Part 1, Touchscreen experience, attitude and expectations
Questions 6 - 8. The focus of the study is movement in an interactive touchscreen environment. These questions therefore narrowed the focus of respondents' relationship to ICT onto the context of touchscreen interaction. This was to be able to evaluate whether the answers for the study hypothesis were influenced by tendencies in the respondents' approach to touchscreen interaction.

Part 2, Immediate experience of objects in experiment
Questions 1 - 2. These questions meant to capture the respondents' immediate experience of the objects they had been interacting with. This was the most important question in the study. The questions were brief and unambiguous.

Part 2, Detailed response on objects in experiment
Questions 3 - 6. These questions asked for further details about the objects. The inquiry into objects experience was split among the immediate questions 1 & 2 and these detailed questions 3 - 6 to make the respondents not reflect too much when answering questions 1 & 2. The details are interesting, but require reflection which might spoil the affective state right after the exercise.

Part 2, Interpretation of objects
Questions 7 - 10. These questions elicited information on the material and affective experience of the objects. The objects had been designed to emulate certain materials, but respondents might not have associations to these materials, as already suggested by the TAW students' review and maybe respondents also experienced the objects as having a certain affective profile. This latter being an aspect not considered during object design. The expectation was that answers would not be consistent.

Part 2, Experience of task
Question 11. This question had respondents report their experience of the courses and whether these environments had affected their impression of the object(s). This was to understand the relationship between object and context and how this relationship had affected the experience of the objects and thus the overall experience of the motile patterns.

Part 2, Experience of context
Question 12. This question addressed the respondents' experience of performing the task in relationship to the touchscreen environment.

Part 2, Process of answering the questions
Question 13. At a late state in the data-collection process a question regarding whether the respondents had actually re-visited the exercise during the answering process was added via the Google form.

The question categories reflect the five interaction design elements that the exercise models (section 11.3). Table 7 illustrates how the questionnaire categories cover the model elements. Methodology is of course not within the interaction design model.

Type	Category	Question
User:	Demographic data	1 – 2, part 1
	ICT experience, attitude and preferences	3 – 5, part 1
	Toucscreen experience, attitude and expectations	6 – 8, part 1
Experience: (focused on functional animation)	Immediate experience of objects in experiment	1 – 2, part 2
Tool:	Detailed response on objects in experiment	3 – 6, part 2
	Interpretation of objects	7 – 10, part 2
Task:	Experience of task	11, part 2
Context:	Experience of context	12, part 2
Methodology:	Process of answering the questions	13, part 2

Table 7. The question categories mapped in relation to the elements of interaction design.

Not all questions were obligatory, as I from personal experience find this feature demotivating for completing a questionnaire. The most important questions were obligatory.

The questionnaire was distributed in Danish, but Appendix Aprovides a full English translation and an impression of the continuity of the questions.

11.5 Collecting data

The study was disseminated in March and April 2013 via various digital channels (Table 8) and by actively seeking up specific groups of respondents.

The broad test-population made collecting a representative dataset both easy and challenging. Easy because no people exhibiting a specific profile had to be convinced to participate, and hard as the test-population required a broad and effective dissemination to achieve a suitable quantity. I expected data-collection to be easy, but the initial target of 1000+ respondents quickly stood out as unrealistic.

The app,-model allowed pushing the app to respondents who would then perform the test when and where they liked. The respondents were therefore in control of the test situation.

Implementing the questionnaire in Google forms enabled real time collection of data. As soon as respondents pressed ”submit”, then their answers got registered. This was valuable for following the datacollection progress as the respondents population could be progressively evaluated and initiatives to push the study to certain demographical groups initiated.Table 8 lists and comments the channels used for disseminating the iOS App. I deliberately distributed the app-link outside the geographical area of Aalborg and Aalborg University. I heard about respondents from most parts of Denmark, but did not collect data on this parameter.

Channel	Comments
Personal Facebook profile	I have 175 Facebook connections. I posted an intro + app link and asked people to participate and to share (shared 5 times). I put up teasers before the app was ready and put up reminders three times during the two months where the experiment was active.
Personal LinkedIn profile	I have 417 LinkedIn connections. Same procedure as for personal Facebook.
Personal Google Plus account	I have 37 Google Plus connections Same procedure as for personal Facebook.
Instagram	I did not use Instagram
Twitter	I did not use Twitter
Personal profile on hum.aau.dk	The link was available on my personal profile on AAU.dk
Email to familiy, friends and colleagues	Link for the app was distributed via email. Some of these connections requested the link to be able to forward to their network.
My childrens primary school	The link got distributed via the headmasters online newsletter and send via an online communication forum to the parents in my two sons classes.
Primary schools in Aalborg	Contacted via phone and send the link to the adminstrative office and asked to have it distributed
Odder primary school	Contacted and got the link put on the frontpage of Odder primaryschool as they had a project that distributed iPads to all their pupils. See Figure 17
Highschools in Aalborg	Contacted via phone and send the link to the adminstrative office and asked to have it distributed
IDM Facebook group	The facebook group of my science group at Aalborg university. Many past and present students are members. Same procedure as for personal FB.
AAU departemental newsletter	Link distributed via the departmental newsletter with a request to participate and share.
Videnskab.dk	Contacted videnskab.dk and they ran a short entry on the experiment for a few weeks[18].This was the single one activity that generated the most respondents.

Table 8. Overview of the channels used for distributing the iOS App.

[18] videnskab.dk/teknologi/ipad-og-smartphone-hjaelp-en-dansk-forsker-med-gore-dem-bedre

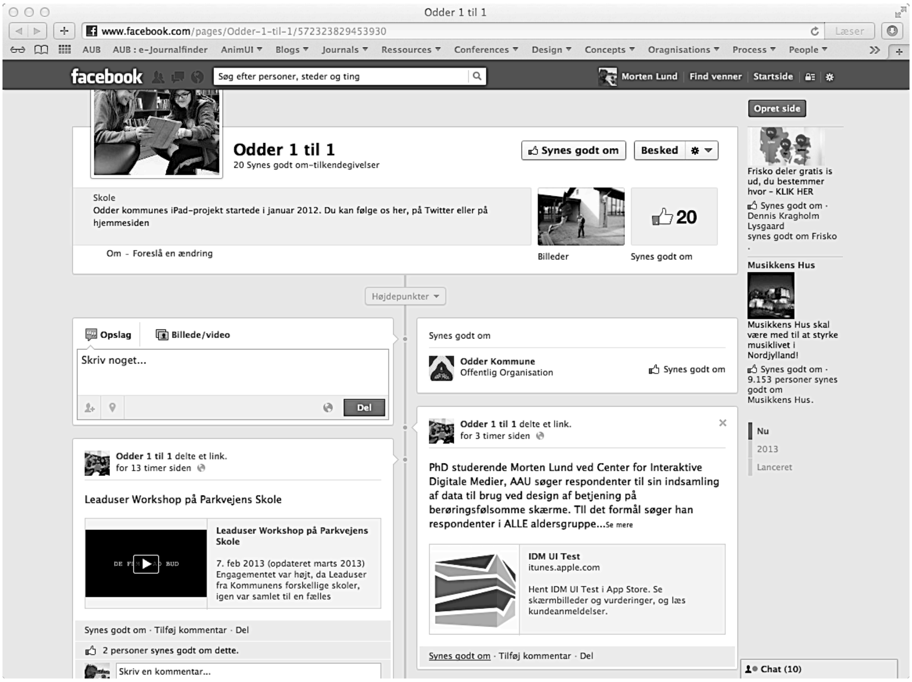


Figure 17. Example from Facebook pushing the study to Odder School.
The post was made by the page administrator.

One advantage of questionnaires is the respondents's control of the answering process. But the situation is formal and constructed as far as the questions require the respondent to make him-/herself available and reflect upon pre-set questions and possible answer categories for a specific subject. The respondent might also sense the intention of the questions and thus answers become a reflection of respondents interpretation of this intention - a socalled ”context effect” (Olsen, 2006, p. 61). The biggest concern for this study was whether some respondents would submit multiple answers or whether they performed the test in solitude (as intended) or as a social event.

These scenarios presented the greatest risk to compromising data-integrity. A first person format (you, yours) was used in the introductory text to indicate the solitary requirement, but the text did not explicitly ask respondents to complete the test in solitude.

Based on the frequency of responses, 250 responses became the ambitious, but realistic aim. The study was closed when no new responses had been received for a month (May 2013). The population then totaled 224 respondents representing 101 female (46%) and 123 male (54%) respondents. All assumingly Danish speaking. Compared to the overall Danish population as of January 1st 2013 consisting of

49,6% female and 50,4 % male, this distribution appear representative of the gender variable.

11.5.1 Young children and elderly

A concern was to get data from the groups that would not naturally get into contact with a request to participate in the study. The very young children aged 0-9 would probably not, by own initiative, engage in a questionnaire activity and the 70+ age-group were not expected to be regular tablet-users. This trait made this group particularly relevant as it might contain respondents with limited or no touchscreen experience. The children, on the other hand, could be expected to have touchscreen experience on a level of familiarity unknown to previous generations by that age. They would represent so-called ”digital natives” (Prensky, 2001). Sessions were therefore arranged at two kindergartens and two homes for elderly people where the research assistant and I sat with respondents while they performed the test. With the children we read the questions out loud and assisted in entering answers. With the elderly we remained as passive as possible.

At the homes for the elderly, the respondents were mostly capable of completing the experiment without any supervision. Respondents sat in the common living room and did the test in solitude. The supervision was limited to confirming that the respondents had a correct interpretation of the questions. In one case the respondent had difficulties striking the radio buttons in the questionnaire and thus I performed the selection from her directives. In another case I went through the test with a sweet and talkative lady who reflected upon the questions and her own performance. Only afterward did the staff inform me that she was suffering heavily from dementia and did often not remember having eaten just minutes after finishing her meal. This incident indicated a successful implementation of the intended simplicity of the study. But more importantly it indicated that the associations required for reflecting over answers did not require any particular contextual knowledge or cognitive skills.

The kindergarten kids covered the age group 0-9. This age group – in particular 5 and below generated data of very fluctuating quality. This could be explained by the circumstances of being on your own, with an unknown adult, in a room (we left the door open), asking strange questions about something arbitrary on an iPad. We did however, not experience much discomfort from the participating children. At both kindergartens the children cued up outside the test-room to try ”the game” and were eager to participate. In one instance a boy made oral ”engine-noices” during the exercise and explained how the circles could represent different vehicles. He clearly used the motile patterns to identify and then characterise the object affordances. Our common impression was, that the children understood the exercise and did identify different object versions. But these experiences were often lost among inconsistent responses or not reported at all.

No children had trouble completing the exercise, but the questionnaire format was too complex and abstract for small children. Some questions were hard to explain because they require a level of reflection and selfawareness that is not present at that age. The frustrations gained from some questions spilled over to other questions. The sessions at the kindergartens became a test of the methodological approach and not data collecction for the study subject. The correct method would have been the exercise in combination with oral questions, written notes and video-observation. In particular video would have been really useful as some of the children made statements about the exercise that supported the study hypothesis and expectations. But we were not prepared and did not have bandwith to take notes and supervise at the same time. The kindergarten data collection was completed as removing the age-group from the study population would be possible later. This sample could then be analysed in isolation.

The sessions at the kindergarten and homes for the elderly constitutes data-collection circumstances different from the remaining age groups as a test-supervisor was present. The Kindergarten group, 0-9 of age represents 24 respondents (10,7% of study population) and the elderly homes match the 70+ age group which represents 12 respondents (5,3% of study population). The research assistant and I agreed that we did not observe our presence affecting the responses. But there is a risk, that the respondents tweak their answers to please the supervisor, even when made aware that they should not do this, and even when they say they do not do this. The results from the 70+ age group and the kindergartens therefore do represent a different set of results in comparison to the results from those who completed the test without any supervision. Adding to this is the dubious validity of the answers provided by the kindergarten kids.

To maintain integrity of the data set I therefore leave out the 36 responses representing the age groups 0-4 and 5-9, which covers the kindergarten kids, and the age group 70+, which covers the responses from homes for elderly people. This settles the study population at 188 responses.

12 RESULTS

This section presents and discusses the study results. The survey questions are presented along with the results from each question. The full data set is presented for each question in the form of frequency tables including both absolute numbers and percentages. There is therefore no appendix presenting the data. A general discussion and conclusion completes Part II.

For each question five aspects will be presented:

1. The question
The actual question as phrased in the questionnaire. Most questions contain statements or categories that the respondent is asked to rate or agree/disagree with. These are referred to as ”sub-questions”. The full questionnaire is available in Appendix A.

2. Rationale
Motivation for presenting question. Relation to research question.

3. Expectation
Expected answer when designing question

4. Result
Numeric results. All percentages are in relation to the number of respondents for that particular question. Unless otherwise noted then the question is answered by 188 respondents. Some questions were not obligatory and therefore not answered by all 188 respondents. Also it turned out that answering one sub-question in the Google Form allowed respondents to skip other sub-questions. Even when the question was marked as obligatory. The total number of respondents therefore varies.

5. Comments
Summary of results, interpretation and critique

12.1 Part 1, Q 1, Obligatory: Gender and Age

Question	*Please state Gender and Age*
Rationale	Demographic information to assess representativity of the respondents group.
Expectation	Representativity expected.

Results

Gender	Count
Female	80 respondents , 43%
Male	108 respondents, 57%

Age	Male		Female		Total	
10-14	8	4,2%	4	2,1%	12	6,4%
15-19	6	3,2%	10	5,3%	16	8,5%
20-29	19	10,1%	6	3,2%	25	13,3%
30-39	22	11,7%	12	6,4%	34	18,1%
40-49	27	14,3%	29	15,4%	56	29,7%
50-59	17	9%	15	8%	32	17%
60-69	9	4,8%	4	2,1%	13	6,9%

Comments As per section 11.5.1, then the lower and upper age-groups have been removed. The distribution of gender is lopsided with 14% more males than female respondents. The gender distribution across age-groups reveals that the ”surplus” of male respondents is significant in the age-groups 20-29 and 30-39 which has 23 more male than female respondents. This could be explained by an appeal of the studys technological focus to males whom by common understanding are more interested in technology than females within these age groups that are (borderline) digital immigrants (Prensky, 2001). These males would therefore be more inclined to particpate in the study. Q5 concerns ICT preference and Laptop PC and Tablet are the most popular devices (section 12.5). Within the age groups mentioned (20-39), then 34 males vs. 15 females prefer Laptop PCs and 35 males vs. 18 females prefer Tablets. For either device the male to female ratio is more than 2:1 which is far above the overall gender distribution of the study sample. This could indicate validity in the "Male-ICT-interest" explanation of the higher number of male respondents in this age-group.

Age distribution reflects the Danish national age-distribution fairly well19. A spike at the 20 year span and a little less in the 40-49 group would provide a correct match.

12.2 Part 1, Q 2, Obligatory: Education

Question *Please enter your most recently completed or ongoing education*

Rationale Demographic information to assess representativity of the respondents group.

Expectation A lot of activities were initiated to secure broad composition (section 11.5). Hoped not to contain too many academics.

Results

Education	Male	Female	Total	
1. Kindergarten	-	1	1	0,5%
2. Elementary school	16	5	21	11%
3. High school or similar	12	12	24	12%
4. Coll. of Education	-	1	1	0,5%
5. Tech. Coll. or similar	33	26	59	31%
6. University	44	35	79	42%
7. Self-educated	3	-	3	1,5%

Comments A majority of academics (42%) represents a mismatch to the national educational level[20]. This is probably due to the channels of distribution which epicenters to my personal network. The announcement at

[19] www.dst.dk/da/Statistik/emner/befolkning-og-befolkningsfremskrivning/folketal (accessed October 2016).

[20] http://www.dst.dk/da/Statistik/emner/befolkningens-uddannelsesstatus/befolkningens-hoejst-fuldfoerte-uddannelse (accessed October 2016).

Videnskab.dk provided about 50 respondents. This forum may also have an overweight of academics. Gender distribution is fairly even in perspective of the overall overweight of male respondents

Education, and in particular the academic respondents, could be relevant variables.

12.3 Part 1, Q 3, Not obligatory: ICT Experience

Question *Please indicate whether you have experience with the below digital technologies:*

1. Computers operated via keyboard and mouse (or similar)
2. Xbox, PlayStation, or similar
3. Microsoft Kinect, Nintendo Wii, or similar
4. PSP, Nintendo 3DS, PlayStation Vita, iPod, (or similar)
5. Mobile phone without touchscreen
6. iPhone
7. Other smartphone (Samsung, HTC, Nokia, Sony, or similar)
8. iPad or iPad Mini
9. Other Tablet (Android, Windows, or similar)
10. e-Book reader (Kindle, or similar)

Rationale Respondents' ICT experience could be a factor in respondents evaluation of the exercise.

Expectation A high level of experience across most devices, but less experience for categories like ”other tablet” and ”e-book reader”. High iPad experience.

Results

Category	Yes		No		Don't know		Total
1. PC, WIMP UI	187	100%	-	-	-	-	187
2. Game platform	147	78,5%	38	20%	2	1,5%	187
3. Game Kinect	156	83,5%	30	16%	1	0,5%	187
4. Game handheld	139	75%	47	25%	-	-	186
5. 2nd Gen. Mobile	183	93,5%	5	6,5%	-	-	188
6. iPhone	156	83,5%	31	16,5%	-	-	187
7. Other Smartphone	148	80,5%	36	19,5%	-	-	184
8. iPad	181	96%	7	4%	-	-	188
9. Other tablet	81	44%	102	55%	2	1%	185
10. E-book reader	52	28%	131	71%	2	1%	185

Comments	Numbers show a high level of experience across all devices. All respondents have PC experience and a lot of experience with gaming platforms too. Even handheld gaming platforms have 75% coverage. It is no surprise that 83,5% report iPhone experience, but a high number for a specific device. The educational demographics does not explain this as both yes and no are evenly distributed across this variable, but the age variable show that 74% (23) of the no's are in the age groups 40-69. Other Smartphone show coverage and age patterns similar to the iPhone. 96% report experience with the Apple iPad. This is no surprise as the study requires access to an iPad. Extensive iPad experience is therefore as expected. For Other tablet and E-book reader the numbers change and respondents' cumulative experience is less than 50% for either category (item 9 and 10). These numbers are from 2013, and surprisingly high compared to expectation: Other tablet is 44% and E-book is 28%. These numbers are explained by the educational profile among respondents: 47% of positive other tablet experience are university respondents and 90% of positive E-book experience are university and Tech. college respondents. The respondents group is characterised by a broad ICT experience. No particular device category stands out as a variable that could have affected the respondents' feedback on the exercise. On the contrary, then this broad experience is a strength as it tests the intended de-contextualisation. If ICT experience influence how the objects are experienced, then patterns will emerge in the responses of questions 7 and 9 of part 2. The broadness in ICT experience is remarkable from a societal perspective.

12.4 Part 1, Q 4, Not obligatory: ICT attitude

Question	*How do the following statements match your attitudes to digital technologies?* 1. I think digital technology is interesting 2. I try to be among the first to try new digital technologies 3. I learn to use digital technologies as the need arises 4. Digital technologies are an integrated part of my life and my activities 5. I am aware, that the technology I use, is digital
Rationale	The question concerns the respondents' general feelings towards ICT. Tendencies at either end of a criticism spectrum could be a variable in the respondents' experience of the exercise.

Expectation No negative bias is expected. Probably no-one with a negative attitude towards ICT would voluntarily participate in a study about ICT.

Results

Sub-question	Yes		Neutral		No		Don't know	
1. Interesting	167	90%	18	9,5%	-	-	1	0,5%
2. First mover	64	34%	74	40%	46	25%	2	1%
3. Need to know	169	91%	13	7%	3	1,5%	1	0,5%
4. Integrated	168	91%	12	6%	3	1,5%	3	1,5%
5. Aware	133	71,5%	39	21%	8	4,5%	6	3%

Comments Out of 186 total responses, the attitude is generally positive as indicated by the 167 (90%) positive answers to sub-question 1. As for the ICT enthusiasm of the respondents group, then sub-question 2 has 65% (40+25%) respondents answering that they are not among the first to try new technology. This means that the majority of respondents do not present themselves as interested in technology for the sake of technology. The positive 34% might be enthusiastic, but could therefore also be critical. This distribution is not a concern. This interpretation is supported by the easy going attitude indicated by the 91% positive responses for sub-question 3 where respondents report that they learn new ICT on a need to know basis. Following the broad ICT experience reported by Q5 (ICT experience) then the overall positive attitude is not surprising and indicates consistency in the responses.

Sub-question 4 appears superfluous, but supports sub-question 3 as the numbers are almost the same. The awareness of technological foundation indicated in sub-question 5 is interesting as the expectation was for more negative answers. But considering the previous answers, then the level of positive answers makes sense. Some respondents might have indicated ”Neutral” as awareness is ambiguous. The Danish term was ”bevidsthed”, which is also ambiguous. Question is too abstract and too academic to be really useful.

The results do not establish ICT attitude as a significant variable as the respondents do not present a significantly ICT positive of ICT negative profile.

12.5 Part 1, Q 5, Not obligatory: ICT preference

Question *Which digital technologies do you prefer for your activites?*

1. Stationary computer
2. Laptop computer
3. Tablet (iPad, or similar)
4. Smartphone

	5. Ordinary mobile phone 6. Hand-held gaming console (PSP, iPod, or similar) 7. Stationary gaming console (Xbox, Wii, or similar) 8. Other

Rationale The question requires the respondents to rank the device categories. The aim was to establish an indication of how touch devices are ranked in comparison to other devices. The challenge was to find a proper and understandable measure. This produced the phrase ”for your activities” which is deliberately open for interpretation, but does establish a parameter for ranking.

Expectation A preference for laptop and smartphones.

Results

Sub-question	Prefer		Neutral		Prefer not		Not relevant		Total
1. Stationary PC	6	4,5%	67	50%	54	40,5%	6	4,5%	133
2. Laptop PC	146	78%	34	18%	5	3%	2	1%	187
3. Tablet	160	86%	22	12%	-	-	4	2%	186
4. Smartphone	134	72%	37	20%	7	4%	7	4%	185
5. Old phone	21	12%	47	26%	99	55%	13	7%	180
6. Game handheld	18	10%	58	32%	64	36%	39	22%	179
7. Game console	42	23%	55	31%	46	25,5%	37	20,5%	180
8. Other	9	6%	41	28%	10	7%	86	59%	146

Comments Laptop PC and Tablet are clearly the preferred ICT platforms (items 2 and 3). The tablet reaching 86% preference and having no prefer not marks. The Smartphone (item 4) follow these devices, but also collects 4% prefer not marks and a few more neutral marks than the other two platforms. The overall preference tendency is towards the mobile/portable platforms.

The high preference for tablets is not a surprise and in accordance with the ICT experience (Q3), gender (Q1) and educational profile (Q2) reported. The study probably attracted respondents who already had a preference for this platform. This effect was unavoidable, but countered in two ways: 1) by actively seeking out respondents with no tablet experience. Unfortunately these have been excluded from the study population. 2) by neutralisation of known interactive digital system context leading to the abstract system model (section 11.1).

The question has an ambiguity for how to understand preference: Is it ”wish to use” or ”like to use currently”? The latter is the intent and should be apparent from the question phrase: ”for your activities”. Either interpretation creates valid data as both wishful and actual usage preference is a result of experience with ICT which according to Q3 and

Q4 is extensive and positive.

The results could be viewed in relation to the age-groups. But the test-population reflects the national age profile and results are therefore representative. The overweight of academics (42%) might skew the responses. Looking at only the academics preferences, then 44% (64) of the prefer laptop responses come from academics and 40% (65) of the prefer tablet responses come from academics. The academic part of the test-population has therefore not skewed the responses more than their overall presence in the test-population allows. Overall then 78% prefer the Laptop PC, and 86% prefer the Tablet. These numbers cover much more than the academic part of the test population.

The respondents did not have to mark all items, which are also reflected by the totals. The question asks for preference, but clearly items 5-7 have inspired respondents to also state neutrality and no preference for these functionally specialised devices.

59% report Other (item 8) as not relevant. This could mean that relevant ICT categories are covered by the preceding device categories.

The relatively low number of not relevant responses also indicate that the phrase ”for your activities” was meaningful to respondents.

The ditribution of responses in relation to age-groups and educational profile reveal an even distribution meaning that it is not only the younger age-groups that prefer game consoles, nor the older groups that prefer ordinary mobile phones. In 2016, this device category would probably not be included.

12.6 Part 1, Q 6, Obligatory: Touch device frequency

Question	*How often do you use devices with a touchscreen?*
Rationale	The frequency of touchscreen usage indicates how integrated this technology is among respondents. The frequency indicates familiarity and could affect respondents’ approach and expectations to touchscreen interaction as regular use advance certain interaction patterns and concepts as normative. This progressive education/adaptation of users to certain interaction patterns is observable in the unlock pattern of the iPhone which has evolved from a skeumorphic mechanical slider to a ”flat content as interface” design that is only meaningful to the first time user if they have previous experience with the ”swipe to unlock” gesture” introduced by the first iOS generations. Figure 18 show a first generation iOS unlock screen to the left where the mechanical motion metaphor is enhanced by the graphics, symbols and marquee like right-moving change is text-colour. To the right is the iOS7 version of the same pattern, but now all skeumorphism is gone and only the

actual text and the marquee effect remain. To my knowledge this update did not present any usabilty issues. This could be expected if no prior experience with ”swipe to unlock” was present in users.

Figure 18. Apple iOS Unlock screen evolution.

Expectation Regular usage among the majority.

Results

Daily		Weekly		Now & Again		Rarely		Never	
183	97,5%	1	0,5%	2	1%	2	1%	-	-

Comments Out of the 188 total responses, 97,5% report daily use of touchscreen devices. None report never to have used touchscreens.

This is in accordance with the reported ICT experience (Q3) and preference (Q5). These reports indicate an overall familiarity with touchscreen interaction. The normative effect is countered by the abstract system model of the exercise.

The high frequencey of touchscreen device usage represent a risk that the described adaptation to certain interaction patterns has happened and that this influence the users experience of the circles as they have certain expectations. However, the almost 100% daily use among respondents also make this parameter useless as a variable.

The 5 respondents (2,5%) that do not report daily touchscreen usage are all males and distributed across the age groups 10-14, 40-49 and 50-59. Educationally they are either Elementary school or

Tech.College or similar. None of them try to avoid touchscreens and none of them report touchscreens as difficult to use (Q7).

12.7 Part 1, Q 7, Not obligatory: Touchscreen experience

Question *How do the following statements match your experience with touchscreens?*

1. I try to avoid touchscreens
2. I think touchscreens are cool
3. Touchscreens make me want to use digital technology
4. Touchscreens are difficult to use because I can't see what can be pressed and pushed
5. I experience touchscreens as dynamic and full of movement

Rationale The respondents' experience with touchscreen devices will flavour their approach to any interaction with touchscreens and thus also the study exercise.

Expectation A positive approach was expected.

Results

Sub-question	Yes		Neutral		No		Don't know	
1. Avoid	2	1%	8	3,5%	178	94,5%	-	-
2. Cool	178	94,5%	9	5%	1	0,5%	-	-
3. Motivates	131	69,5%	47	24,5%	8	4%	2	1%
4. Difficult	16	9%	36	19%	135	71,5%	1	0,5%
5. Dynamic	121	65,5%	53	28%	8	3,5%	6	3%

Comments Out of 188 total responses 94,5% report a positive approach to touchscreens (sub-question 2). Sub-question 1 and 2 appear to have been perceived as opposites as the answers are almost identical.

69,5% report that touchscreens motivate their use of digital technology (sub-question 3). Whether the question is to be understood as touchscreens having an overall positive impact on digital technology usage or whether it is only ICT with touchscreens, is a little ambiguous. The question was phrased like this to avoid mentioning specific devices and to focus on the touchscreen. In the understanding of touchscreens motivating the use of touchscreen devices, the question confirms the attitude expressed in sub-questions 1 and 2. These attitudes are potentially factors for the high Tablet and Smartphone preferences reported in Q5. However, this question also elicit 24,5% neutral and 4% negative responses which show that the touchscreen modality is not an ICT attraction to all users.

Sub-question 4 addresses the general experience of touchscreen interaction by asking about affordances. 71,5% do not find the affordances difficult, but 9% do find them difficult to perceive. This is relatively many – almost 10% who are aware of such issues when asked. An observation-based study would probably increase this number. The general positive experience of interaction 71,5% is just below the 86% that report tablet preference and 72% that report smartphone preference in Q5. In combination with the high touchscreen use frequency (Q6), then the respondents seem to have much experience with touchscreen devices and appear confident in interacting with them.

As for the characterisation in sub-question 5 where movement is directly addressed, then 65,5% agree in the proposed characterisation and 28% are neutral. The interesting aspect is the few disagreeing answers. The question has an inclination, but the answer options are as open as possible, including the question being not obligatory. Yet only 3,5% do not agree and 3% don't know which are so low numbers that the neutral and agreeing responses gain credibility.

Presenting the group of question as attitude questions, rather than experience questions, would have been more to the point. However asking like this requires the respondent to report attitudes based on personal experience and not attitudes based on secondary sources.

The attitudes reported are in line with the positive approach reported in previous questions.

12.8 Part 1, Q 8, Not obligatory: Touchscreen interaction

Question *The statements below all begin with "When I use a touchscreen…*

1. … it is easy to keep the overview of the activity"
2. … I have a good sense of what I am doing"
3. … I have a good sense of what happens and what will happen"
4. … I often make mistakes"
5. … I am afraid to make mistakes"
6. … I find it easy to become engaged with the activity"
7. … I want to examine and play with the content"
8. … I like that it is my fingers that I use for the activities"

Rationale Insight into the detailed experience of, expectation towards, and feelings involved in touchscreen interaction, will allow assessment of these variables against responses to the study exercise.

Expectation An overall positive experience of touchscreen interaction.

Results

Sub-question	Yes		Neutral		No		Don't know		Total
1. Overview	125	67%	53	28%	5	2,5%	5	2,5%	188

2. Feeling of presence	142	76%	39	21%	4	2%	2	1%	187
3. Feeling of effect	131	69,5%	50	26,5%	4	2%	3	1,5%	188
4. Often make mistakes	25	13,5%	61	32,5%	100	53%	2	1%	188
5. Afraid make mistake	9	5%	14	7,5%	163	87%	1	0,5%	187
6. Engaged	109	58%	58	31%	16	8,5%	5	2,5%	188
7. Explore & play	128	68%	48	25,5%	9	4,5%	2	1%	187
8. Fingers	142	76%	40	21%	4	2%	2	1%	188

Comments

Sub-questions 1, 2 and 3 address the design guidelines presented by Baecker and Small (1990) and in particular the relationship between time and motion. The aim was insight into whether the effects of these guidelines are present in respondents touchscreen interaction experience. The majority of responses confirm the three statements: 67%, 76%, and 69,5% respectively. This is followed by respectively 28%, 21%, and 26,5% neutral responses. Respondents seem to report the effects expected from the guidelines. The few no and don't know answers are of course interesting as they indicate usability issues in the interaction.

Sub-questions 4 and 5 address the same challenges in perceiving affordance as sub-question 4 of Q7. Only these questions very specifically ask about frequency of mistakes and then the overall feeling of security in the interaction. 87% are not afraid to make mistakes. This could be understood both as not concerned about the risk, because it doesn't happen very often: 13,5%, as per sub-question 4. Or it is because when mistakes happen then it is not a problem to revert, navigate back, etc. It might also be that these responses are device related, and thus a function of the interaction design concept familiar to the respondents as discussed in relation to Q6.

Sub-questions 6 and 7 address the feelings respondents have towards the activity and content they engage with on touchscreen devices. The questions are not very specific, so from this perspective, then the respectively 58% and 68% positive answers are surprising. Of course the answers provide no insight into neither activity nor content, so if all respondents only played ”Fruit Ninja”[21], then responses should of course be seen in this context. No questions ask about types of use. Answers are therefore only to be understood as an indicator of a generalised attitude.

[21] http://fruitninja.com (accessed October 2016).

Sub-question 8 was inspired by the embodied approach to interaction design (Dourish, 2001) and tried to ask explicitly about respondents' attitude and feelings about not using some proxy, like a mouse, to manipulate the interface and content. The question stood out as a bit awkward, but seems to have been well received as all 188 respondents have answered. 76% like to use their fingers for whatever they are doing. 21% are neutral and only 2% are negative about this modus of interaction.

The positive/neutral attitude reported in sub-questions 6 and 7combined with the likewise positive response to sub-question 8 could be linked as the immediacy offered by the direct body (finger) interaction creates this feeling of engagement and support for exploration. This is a hypothesis not answered by the study.

12.9 Summary survey Part 1

The questions on demography, ITS experience, attitude and preference and similar questions about touchscreens do not reveal any problematic bias in the dataset.

188 respondents total. 12% overweight of men primarily in the 20-39 age group probably due to the ICT subject. The overall age distribution matches the Danish national age distribution fairly well. 42% of respondents are academics. The ICT experience level across device and usage types is high. Apple iPad experience stand out with 96%, but the iPad centricity of the study explains this. The attitude to ICT is positive, but does not appear uncritically enthusiastic. The ICT preference shows mobile platforms to be the most popular. 97,5% report daily use of touchscreens. This represents a possible familiarisation among respondents towards certain interaction patterns in commercial devices which could affect how the exercise is experienced. The extensive touchscreen experience have the respondents report a generally positive attitude towards touch-based interaction. To a large extend the respondents agree to characterise touchscreen interaction as dynamic, and safe in terms of handling errors. Respondents like to use touchscreens and do not mind using their fingers for interacting with the interface and content.

The overweight of academics appear to be the most critical variable. The probable ICT enthusiasm among males in the 20-39 age-group also represent a possibly biased variable.

12.10 Part 2, Q 1, Obligatory: Different versions of circle & why

Question	*A. Did you experience different versions of the circle?* *B. If 'yes', then what gave you this experience of difference?* 1. Hard/easy to move

	2. Change of shape 3. Change of size 4. Reaction 5. Colour 6. Sound 7. Other

Rationale This was the most important question of the study. The question asks for the respondents' immediate experience of the objects. This was done in the simplest possible way to require a minimum of reflection: yes or no.

This question asks for difference in general and not a quantitative number or a sematic characterisation. Such accounts are requested in later questions. Collecting the very first impressions at a non-specific level was important as detailed questions would require reflections that could potentially affect the immediacy and thus the response validity.

The only way to experience different versions is through the motile patterns. If respondents report different versions, then it means that movement as the dominant associative phenomena instills meaning with the respondents. This would verify the study hypothesis: Movement instills meaning. If respondents did not report different versions, then the hypothesis would be falsified.

Expectation The expectation was that the majority would report more than one version of the circle.

Results

Question A

Yes		No	
180	95,5%	8	4,5%

Question B

Sub-question	Yes		No		Not relevant		Total
1. Hard/Easy to move	164	89,5%	16	9%	3	1,5	183
2. Change of shape	132	73%	47	26%	2	1%	181
3. Change of size	108	61%	67	38%	2	1%	177
4. Reaction	169	93,5%	8	4,5%	4	2%	181
5. Colour	7	4%	151	88%	14	8%	172
6. Sound	4	2%	116	67%	52	30%	172
7.Other	15	9,5%	71	45,5%	70	45%	156

Comments The question had two steps: A and B. Question A asked for difference among circles and question B asked for reason for this difference.

95,5% of the 188 respondents for question A reported experiencing different versions of the circle. 4,5% reported not experiencing different versions. This verifies the study hypothesis: Movement as the dominant characteristic is capable of instilling meaning in the individual interacting with a motile digital object in a touch environment, and it answers the research question: Motion does generate meaning,

The high positive response rate is not unexpected and as the respondents more or less all agree, then no particular demographic variable suggest a bias for confirming the hypothesis. The 95,5% positive responses include all respondents reporting not-daily tablet usage in Q6, part 1.

The 8 respondents who report not seeing different versions are 6 males and 2 females distributed across age groups 15-19 (1 male, 1 female), 20-29 (1 male), 30-39 (1 male), 50-59 (1 male, 1 female) and 60-69 (2 males). All 8 use touchscreen on a daily basis (Q6, part 1). None of them try to avoid touchscreens, and none of them finds touchscreens hard to use (Q7, part 1). But the female in the 15-19 age group does answer no to touchscreens being dynamic and full of movement (Q7, part 1). All of the 8 report ICT as generally interesting (Q4, part 1) and they also all report a preference for Tablets (Q5, part 1). Finding a common negative touchscreen denoiminator or ICT bias among the 8 is not possible. The reason for not reporting different version must therefore be grounded in individual aspects not covered by the questionnaire.

The high positive response rate could be caused by the exercise design: Asking respondents to perform the same task three times with 5 identical objects and then ask whether these 5 objects are different, contains a strong signifier about awareness of difference. This is correct and therefore the questions following this ”immediate experience question” ask how many versions respondents experienced (Q2) and details about the basis for this experience are requested in subsequent questions. Questions about the task and context follow at the end of the survey.

The detailed questions will assess the consistency of the immediate experience answers in Q1. The variation among these answers will reveal how subjective experiences shaped the immediate assesment of circle versions and not deductions based on the study design.

Question B asked respondents to report the reason for experiencing different versions. The intent was to gain insight into which motile properties the respondents had noticed. This would indicate which specific properties have the most influence on the experience. Sub-questions 1-4 address the motile patterns and specifically which motile components instilled the experience of difference. 89,5% report Movement of and 93,5% report reaction as reasons for difference (sub-que. 1 & 4). 73% report change of shape (sub-que. 2) and 61% report change in size (sub-que. 3).

It is not surprising that 89,5% report movement of as a factor for discerning among objects. It is more surprising that 9% do not see movement of as a discerning factor (sub-que. 1). Maybe movement of is not interpreted as a distinguishing parameter as all objects are moveable, and the object differences are attributed to the inert movement properties (sub-que. 2-4). From that perspective, then answering no is actually correct. However, all objects have different movement of properties – e.g. Neutral only moves with a non-accelerated speed across the surface and does not gain power from a ”flick” gesture. The different movement of properties are expressed in Table 5.

The intent was for sub-question 2 to address deformation of the circular shape (flattening on the sides and extension into oval) when in contact with the obstacles, and for sub-question 3 to address the changes in size of the basic shape when pressed and released. Sub-question 4 addressed the responsiveness in terms of tensional reaction (effort) upon impact with obstacles. The different motile properties represented by sub-que. 2-4 are not exclusive, but will support one another in creating the united expression of the motile pattern. Respondents awareness of these nuances is not available in the data, but the responses indicate that when asked immediately, then reactiveness is the parameter that stand out. But not how this reactiveness manifested itself via change in shape, size and response effort. Change in shape has 12% more positive answers than change in size, and similarly 12% less negative answers than change in size. This indicates that between these two inert properties, change of shape has the most impact on respondents experience of difference.

Sub-question 4 addresses reaction which is a result of the objects interaction with the surrounding environment (the courses). 93,5% report reaction as a factor for discerning among the objects. It therefore seems that the relationship between the object and environment (obstacles, other objects) is important in getting to know the object properties and thus the ability to discern the objects from one another. The object reveals its properties (affordances) in the interaction with the environment and vice versa, then environment properties are revealed when interacted with via the object – e.g. the obstacles could have been less rigid. Apart from environment, then the respondents’ personal ability to challenge and explore is also a factor and adding to this, is the task and goal driving the activities. These factors will be addressed in subsequent questions.

One out of four respondents (26%) did not indicate change of shape as significant (sub-que. 2). The objects did not actually change shape, as in transforming from round to hexagonal, and answering no is correct in that perspective. However, most objects did change shape upon impact by squashing and stretching and also when dragged or flicked across the courses, but they did not abandon a basic ”roundness”. An even higher proportion (38%) did not report change of size as significant in discerning among objects (sub-que. 3). Three of the objects did change size upon press and then returned to original size upon release. But if the understanding of change of shape and size by some respondents was intepreted as a permanent change, then the no answers are correct. Another explanation is the one offered above, which point to reaction (sub-que. 4) as the motile property that includes both shape and size and thus chosen by respondents when asked about their immediate, un-reflected reason for discerning. In support of this and the view of shape being a more significant indicator of difference than size is also that the total number of respondents is higher for both reaction and shape (181) than it is for size (177).

Across sub-questions 1-4, less than 1,5% on average report the motile properties as not relevant. The data does not provide an explanation for this.

Sub-questions 5 and 6 ask for the missing components colour and sound. Only 4% and 2% report these as reasons for difference. No common variable explain these responses. 9,5% report other reasons for discerning among objects. This is interesting, but again, not explainable from the survey data. The other option was available to allow respondents to answer outside the semantically fixed options represented by sub-questions 1-6. Only 156 respondents answered the other sub-question.

12.11 Part 2, Q 2, Obligatory: How many circles & How different

Question	*A. How many different versions of the circle did you experience?* *B. Mark the degree of difference between the versions you experienced*
Rationale	The number of different circles experienced indicates how well the motile properties have enabled respondents in discerning among objects. The difference among objects is based only on variation among the motile patterns. The number of different objects identified is therefore an indicator of how well motion supports the differential meaningmaking required to discern among objects. As a secondary aim, the question provides a quantitative measure of how many respondents have identified how many objects. The question thereby also develops question 1 further and enable valdation hereof if the high positive response rate is repeated.. The level of difference requested in question B addresses the significance of the individual motile patterns. This evaluation could also explain the number of circles reported. Many different circles will

be reflected by high difference and few versions result in low difference.

Expectation The number of versions would peak around 3, possibly with 2 as the second highest.

Results

Question A.

None		Two versions		Three versions		Four versions		Five versions	
17	9%	29	15,5%	66	35%	50	26,5%	26	14%

Question B.

No difference			← SCALE →				Very big difference
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	5	17	26	33	40	27	23
4,5%	3%	9,5%	14,5%	18,5%	22%	15%	13%

Comments The question had two steps: A and B. 188 respondents answered question A.179 answered question B.

9% report no different version which is twice as many as the 4,5% who reported no different versions as their immediate impression in Q1. This discrepancy might be due to an interpretation of the word versions as they are all visually similar, so when question 1 is almost repeated, then the answer is changed because the respondent rethinks the meaning of ”version”. The 17 respondents represented by the 9% do not deviate on any variables from the groups of respondents that have indicated two or more versions. Those 4,5% (8 respontents) that reported no different versions in Q1 are distributed across answers none, 1, 2, 3, 4, and 5 versions. Half of them maintaining their experience of none. This does not change the conclusion of Q1.

91% report two or more different circles and none of these groups show any particular varians in relation to the variables reported in the questionnaire part 1.

Question A peaks at three versions (35%), second highest is four versions (26,5%), followed by two versions (15,5%). 14% have experienced 5 versions, which is almost the same as two versions. Thus, the majority have experienced three or more versions (74,5%). The average is 3,4 versions. This result indicate that respondents are sensitive to the details of movement as they have successfully discerned among 5 motile patterns and have not had any other associative components to base this discernment upon.

Question B supports the profile seen in question A as the difference reported peaks at 5 on a 0-7 scale. 4 is the second highest value, and 3 and 6 have almost the same amount of marks. The respondents overall evaluation is thereby that the circles are fairly different and as reported in question A: different enough to discern quite well between the five versions.

68,5% of respondents report level 4-7 in difference and 91% report two or more circles. This indicates that the respondents are susceptible to movement as an independently meaningful associative parameter.

The validating results make it relevant to contemplate whether the objects were too different, and therefore designed to fulfill the hypothesis. Q2 and Q1 have revealed agreement among the majority of respondents that the objects are generally meaningful. There also seems to be agreement among a majority that this meaning is constituted by reactiveness and ability to move. The objects were designed to be different, and the identification of difference and thus meaning in movement is expected. The question therefore is: to what level of detail this agreement persists? It is already apparent that respondents do not agree upon the number of objects, but will respondents agree upon characterisation of the objects they have identified? This question is answered by Q7 and Q9 which address how well the respondents agree upon what meaning the objects instil. Q1 and Q2 have established that movement does instill meaning: The respondents have reported that they experience something The detailed questions will then address the character of this meaning by asking: What did you experience? This is illustrated by Figure 19: Is it a duck or is it a rabbit? This is supplemented with questions asking how respondents experienced.

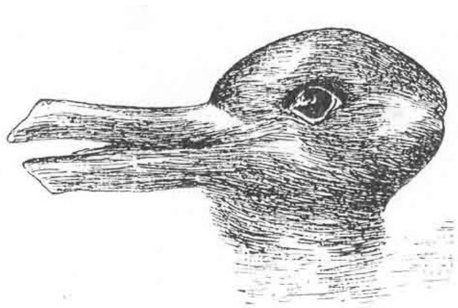


Figure 19. In Q1 and Q2 respondents report seeing something. But what did they see? And do they agree?

Section 11.2 describes the app.-feature that allowed respondents to return to the exercise during part 2 of the questionnaire. The effect hereof is addressed by Q13 and answers are relevant for assessing the process resulting in answers for Q2. Q13, sub-question 4 asks whether going back affected the number of versions reported and sub-question 2 asks whether going back changed the impressions of the circles in a positive direction. Positive is ambiguous as it could be emotional as well as quantitative. Tabulating these two sub-questions with the responses for Q2A provides the following data for assessing whether the reported number of versions is immediate impressions or corrections based on re-visits to the exercise: Of those respondents reporting two versions in Q2A only 2 respondents report both changing the number of versions, and a positive change. For those reporting 3 versions the same tabulation is 6 respondents. For those reporting 4 versions the number is 7 respondents, and for those reporting 5 versions the number is 1 respondent. In total 16 respondents (8,5%), of those reporting 2 or more versions, appear to have increased the number of reported versions based on one or more returns to the exercise. Q13, sub-question 1 asks whether respondents did return to the exercise and 59% of the 188 respondents did return. The 8,5% therefore represent an exclusive group as almost 50% of those reporting 2 or more versions also returned, but did not make positive changes. The possible changes by the 8,5% does not alter the premise of the study: That reporting of difference is based on the meaning found in the motile patterns. The reporting of return and change only confirms that movement instills meaning as it has made sense for the respondents to return and investigate their impressions based on the only available associative stimulant: movement.

12.12 Part 2, Q 3, Obligatory: Identify *Neutral* circle

Question *Did you experience one or more of the circles as 'sluggish' or 'inert'?*

1. Circle 1
2. Circle 2
3. Circle 3
4. Circle 4
5. Circle 5
6. None

Rationale This question investigates whether the respondents would identify the Neutral object version. Purpose was to assess whether this minimal motile pattern would stand out. Neutral exhibited the least possible movement.

Expectation Expectation was that most respondents would not identify the Neutral version and results basically be ”all over the plot”.

Results

Metal		Rubber		Neutral		Paper		Sponge		None	
81	42,5%	47	25%	40	21%	33	17,5%	27	14%	18	9,5%

Comments The results table show how many respondents identified which version of the circle as ”sluggish or ”inert”. The question did not identify the circles by name, only by number (see question above). This was therefore a ”blind test”. The question allowed respondents to pick more than one circle as sluggish. This was implemented as not to hint at a particular version to identify, and to support respondents that might have identified two or more versions based on their sluggishness. 85% of respondents marked only one circle (number not in table). The remaining 15% marked two or more circles as sluggish. The question was obligatory. The 6 options received a total of 248 unique responses.

The question is loosely formulated as respondents are not asked to identify the sluggish version, but whether they experienced one or more objects as sluggish. The respondents also had the option to answer ”none”. The question therefore does not force the respondents to formulate an opinion. The question is about their impression, not correctness in interpretation of emulation. Only 9,5% report none of the objects as sluggish, meaning that the characterisation appears as an appropriate option to the respondents.

The neutral pattern is identified as sluggish by 21%, the rubber pattern receive 25% of responses, but the metal pattern receives an indicative 42,5% of responses. Metal therefore stand out as the motile pattern characterised as sluggish. Neutral is identified by respondents as sluggish, but metal receives twice as many responses and patterns paper and sponge also receive respectively 17,5% and 14% responses. Neutral is therefore not significantly identfied as sluggish or inert.

In principle then any answer is correct as answers depend on the respondents interpretation of ”sluggish” and ”inert”. If the respondent moved his/her finger fast enough, then they would ”loose” the object. This could be interpreted as sluggish. The experience of the object becomes a function of the users bodily movement (finger and arm) in concordion with the behaviour (motile pattern) of the object. The metal version is not very fast nor very responsive to press and collisions. The rubber version is hard, but bouncy. Neutral is as described: ”dead”. All of these descriptions match an understanding of sluggish. One explanation for respondents characterising both metal, rubber and neutral patterns as sluggish could be because respondents in identifying different versions have seen these three, or some of them as similar. Answering either would therefore be correct as they are not discerned by respondents. However, tabulating Q3 with Q2A does not reveal any such patterns.

How paper and sponge make it to the list with above 10% for either is peculiar as these are quite lively and deform upon press, release and collision. Erroneous marking or problems recollecting does not explain how sponge and paper patterns total 31,5% responses. This scenario was the reason for allowing respondents to return to the exercise, as not to create a memory-test. Tabulations do not present any variables that explain the interpretations of paper and sponge as sluggish. Exposing this would require a qualitative investigation.

Metal clearly stands out, but the overall different experiences of sluggishness indicate agreement problems in how to interpret the motile patterns. The respondents reported the 5 circles as fairly different (Q2), but they do not agree on which version to describe by a single characteristic. All respondents have been presented similar exercises, but report different experiences. This prognosticates the results of Q7 and Q9 and thus supports the conclusion made in Q2: That respondents agree on difference and they discern among objects, but they do not agree on how to understand, how to make meaning from what they have experienced. It is a duck-rabbit.

12.13 Part 2, Q 4, Obligatory: Identification of circle details

Question *The below statements commence with: "All the circles ..."*

1. ... have the same colour
2. ... are without sound
3. ... can be moved (Danish: trækkes)
4. ... can be flicked (Danish: kastes)
5. ... behave alike when moved (Danish: træk)
6. ... behave alike when flicked (Danish: kast)
7. ... reminds me of different materials
8. ... are equally easy to use across the 3 courses
9. ... have similar reactions when pressed upon
10. ... have similar reactions when released
11. ... have similar reactions upon impact w. wall or barrier

Rationale These questions elicit further details about the respondents experience of the motile patterns. The questions ask directly about respondents experience of specific properties. The purpose is to identify precisely which properties have been noticed.

Expectation Some qualities will stand out as more significant than others.

Results

Sub-questions	Yes		No		Don't know	
1. Same colour	178	94,5%	7	3,5%	3	2%
2. No sound	140	74%	2	1%	46	25%
3. Movement of	182	97%	4	2%	2	1%
4. Flickable	16	8,5%	103	55%	69	36,5%
5. Alike when moved	9	5%	178	94,5%	1	0,5%
6. Alike when flicked	3	1,5%	99	52,5%	86	46%

7. Resemble a material	109	58%	56	30%	23	12%
8. Equal across the courses	42	22%	143	76%	3	2%
9. Similar when pressed	28	15%	141	75%	19	10%
10. Simlar when released	34	18%	138	73%	16	9%
11. Similar when collision	16	8,5%	159	84,5%	13	7%

Comments All sub-questions were answered by 188 respondents.

The majority of respondents have registered that the circles are visually alike. The 94,5% answering same colour match the 88% (+8% not relevant) that reported colour as not setting the circles apart in Q1.

74% agree that the objects are without sound, but 25% answers don't know. This is consistent with the numbers from Q1. If answering don't know is the same as ”I did not notice”, then an interesting research project would be the relationship between movement and sound. If respondents were certain, then they would have answered yes or no. Answering don't know indicates an insecurity about the presence of this object property. A property that could be expected, but was not there.

97% agree that the circles all exhibit movement of. 3% report no and don't know. These numbers are in line with Q1 and Q2.

Sub-question 4 concerns the objects ability to be ”flicked” or ”thrown across the surface”. The question provides insight into the gestures used by the respondents. A concern for the exercise was to inspire respondents to explore the object properties via different gestures. Flicking being one that might not be natural to most respondents as it has connotations of play and does not correspond well to the task of moving circle to X. The open space course (section 11.1.1.4) was designed to inspire playful behaviour and thus the use of flicks to position the circle. Neutral and Metal were genuinely not flickable, so when the question asks ”all the objects …”, then answering no is correct. In this perspective, 36% apparently did not try flicking, but 55% did assess the flickability of the objects correctly (answering no). This indicates a successful design of the courses as respondent must have tried flicking. In Q8, Part 1 68% reported that touchscreens made them want to play and explore. The 55% suggest an overlap between this touchscreen attitude and respondents actual behaviour in the exercise. But tabulation between Q8, part 1 and this sub-question does not reveal any significance.

Sub-question 5 has 94,5% respondents indicate different behaviour of the objects when moved. This is a higher positive responserate than for

Q1 where 89,5% report movement of as a factor for discerning among objects, but not all 89,5% are within the 94,5%. Various tabulations do not explain this increase.

As for sub-question 6, the response-profile corresponds to sub-question 3 about flickability.

Sub-question 7 addresses the respondents association of the objects to a material. An approach to functional animation is emulation of physics and materials (Harrison, Hsieh, Willis, Forlizzi, & Hudson, 2011) like also done for this study (section 11.1.2). The question therefore assesses the respondents association of materiality and creates a baseline for the detailed answers provided in Q7 and Q8. 30% report no, 58% report yes, and 12% report don't know. Whether these answers are based on reflections during the exercise or a result of the question being raised cannot be evaluated via the survey data. However, sub-question 1 of Q13 asks whether respondents returned to the exercise when answering the questionnaire; and sub-question 2 asks whether this affected the impression of circles in a positive direction. Tabulating these answers with the experience of material reveals that 37% of those answering ”yes, all the circles remind me of different materials” also revisited the exercise and this changed their impression of one or more versions in a positive direction. Q13 Sub-question 3 asks for negative changes in impression when going back and 24% of those answering yes to material also answer yes to having changed impressions in a negative direction. It is therefore not possible to say whether those going back have changed the material impression in a negative or positive direction, but it is apparent that the 58% answering yes to material impression are (probably) not all establishing their answers on recall, but on a study of the objects.

Sub-question 8 addresses the relationship between the objects and the three courses as these might have affected the experience of the objects' easiness. 2% report don't know. 75% report no, and 23% report yes. 75% is a significant number of respondents experiencing the objects as presenting different levels of ease for each course. This means that the courses have enabled respondents to experience different properties, or affordances, in relation to the environments, which is a confirmation, in a digital environment, of James J. Gibson's theory of affordances (Gibson, 1979). The objects reveal different properties in combination with the different environments, and depending on the type of gesture made by the user, which again, is also a result of the users' perception of the environment.

Sub-question 9 and 10 specifically address the object properties when pressed and released. These properties are functions of the respondents interaction with the object and have no connection to the environment. Some objects stretched upon press and retracted to passive size upon release. The majority of respondents answer no and thus indicate difference in the objects for press and release.

Sub-question 11 addresses the object properties when getting into contact with barriers or the course walls and thus respondents' experience of the relationship between object and environment. The majority of respondents (84,5%) answer no and thus indicates experience of difference in the object properties when in contact with the course environment.

Overall, then sub-question 3, 5 and 9-11 responses are consistent to answers provided for Q1B sub-questions 1-4.

12.14 Part 2, Q 5, Obligatory: Like/dislike circles

Question *Please state preference and not preferred*
A. Indicate the two circles you liked THE MOST
B. Indicate the two circles you liked THE LEAST

Rationale These questions aimed at eliciting data on the affective relationship to the objects by asking for preference.

Expectation The sluggish versions would be liked the least and bouncy versions liked the most.

Results

Question A: Like most

Sponge		Paper		Metal		Rubber		Neutral		None	
66	35%	41	21,5%	38	20%	23	12,5%	11	6%	9	5%

Question B: Like least

Sponge		Metal		Paper		Rubber		Neutral		None	
68	36%	48	25,5%	34	18%	20	11%	10	5,5%	8	4%

Comments The table presents the highest response count to the left and the lowest to the right. The sequence of the objects is therefore not identical for the two tables. Respondents were allowed to select two circles within each category. In the questionnaire the circles were presented as in question 3: Circle 1, Circle 2, etc..

Comparing the responses show very little agreement among respondents in their affective relation to the objects. The sponge object is both the most liked and the least liked motile pattern. Metal and paper occupy second a third place in either sub-question. They swap position, but receive almost similar response rates. Rubber and neutral both have the least positive and least negative evaluations. On average 4,5% answer none meaning that most respondents have had an opinion. No particular variable identifies the respondent groups for each motile pattern. The 21,5% having a paper-preference show an overweight of males in the 30-49 age group, but no other particular trait. A slight male overweight is also seen in the paper-dislike group, but these are in the 20-39 age group. Education has no significance.

The responses reflect the tendency seen in the responses for Q3 where respondents idea of neutral was applied across all object versions. Similarly in this case where preference and dislike are also very individual and applied without any significance. However it seems that patterns sponge, metal and paper are the most prominent patterns of the 5 available patterns as they constitute top three for either question. These patterns apparently enforce the most positive and negative emotions. Further investigation of these motional patterns could therefore be valuable for understanding the peculiarities creating such diverse affective effects. Rubber and Neutral are not so controversial, but again, there is not agreement among respondents.

The anonymous presentation of the versions (Circle 1, Circle 2, etc.) did not provide any textual associations and the sequence of the objects was randomised. The respondents evalaution of object preference is therefore truely based on personal values as the visual presentation was deprived as much reference as possible and the gestalt of similarity was disrupted for each instance of the test by the randomisation. The de-contextualised exercise does not reference many values beyond the exercise itself. It is not recognisable as some phenomena signifying a culturally common set of values. When asked about number versions, respondents report a fairly high recognition rate across the five versions (Q2). Q7 and Q9 will address what the respondents saw – a duck or a rabbit? The present question adress value and ask for a personal preference based on perceiving and interacting with the same material (the exercise) as all the other respondents, but without any pointers to an external common system of values. The available associative material is very simple and should be fairly value-neutral. Respondents meaning making and evalaution is therefore based on their personal values, experience and expectations alone. Some agreement could be expected – bouncy would be preferred and sluggish disliked. This is confirmed by sub-question 1, but turned up-side down by sub-question 2. This very diverse result is astonishing as respondents show no agreement, but actually report opposing experiences and values. The 35% preference for sponge is dissolved by the 36% dislike for sponge. There does not seem to be any uniform positive or negative motional pattern that respondents agree upon. The associative stimulants are the same to everyone, but evaluated very idiosyncratic. The conclusion must be that the ”duck-rabbit” (Figure 19) is also present in terms of preference.

In connection to functional animation then the diverse results illustrate how the respondents experience is based on the four elements of interaction design (Section 11.3). Any movement designed into a system context will be a function of the designers' understanding of the factors constituting this context and the user using the system (tool) for a task. The functional animation design will be specific to this context. If the design presents a functional and(or) positive emotional experience, like Apples ”slide to unlock” (Figure 18) or ”Pull to refresh”[22] then users will learn it and the pattern becomes a standard, maybe. The point made by this study is that such patterns are not natural – there is no uniform positive, negative or correct movement for specific contexts. Interaction patterns gain a general recognition and acceptance because users learn that this is the way a particular action is performed. When free of context, then the movements are free of any particular meaning and respondents interpretations differ.

The functional and experiential goal of the system context is what functional animation should support and help create. What should be aimed at is establishing design principles as already seen in literature, and eventually catalogues of interaction patterns with motile patterns associated that have an empirically proven effect.

In connection to the initial motivation of the study, then this result undeline how the contextuality of those examples of functional animation I collected would be precisely that: Examples of contextuality (Appendix C). Such a study would have narrowed the scope of functional animation, whereas this study actually opens up the scope.

12.15 Part 2, Q 6, Not obligatory: Absent properties

Question *Certain properties are absent from all versions of the circles.*

1. Did you miss sounds?
2. Did you miss colours?
3. Did you attempt tilting or shaking the screen (to move the circle)?

Rationale Previous questions investigated whether respondents would report properties that were actually absent from the objects and exercise design. This question asks whether respondents would have liked the presence of these properties.

Expectation No particular expectation.

Results

Sub-questions	Yes		No		Don’t know		Total
1. Did you miss sounds?	38	20%	125	67%	24	13%	187
2. Did you miss colours?	67	36%	114	61%	6	3%	187
3. Did you tilt or shake device?	6	3%	181	96%	1	1%	188

[22] First invented for the Twitter app ”Twetie” by former Apple developer Loren Brichter. en.wikipedia.org/wiki/Pull-to-refresh (accessed October 2016).

Comments The majority of respondents did not miss neither sound nor colour. Colour is requested almost twice as many times as sound: 36% report missing colour and only 20% report missing sound.

13% report don't know about missing sound. The possble doubt associated to this don't know makes sound stand out as a more ”controversial” design component than colour as only 3% report don't know for missing colour. This might be due to the contextually invasive nature of sound. Colours are local and limited to the sphere of the user, and vision is the dominant human sense. The overall message is that respondents did generally not miss neither colour nor sound, but would have liked colour to be added more than sound.

Only 3% report attempting to interact with the exercise via the alternative input of device shaking and tilting proposed by the question. These 3% do not share any particular variable like age, gender, education, or ICT preference or dislikes. 96% did not attempt tilting or shaking. This unequivocal response makes this modalty appear un-intuitive for users. Tilt and shake must therefore be applied with consideration in designs and the presence carefully introduced to users. Functional animation could be useful for such activities.

12.16 Part 2, Q 7, Obligatory: Material resemblance

Question *Did one or more versions of the circle resemble a specific MATERIAL?*

Rationale The purpose was to understand how well respondents agree on the associative references of the five motile patterns: Would respondents agree on a material mimicry for each version? If respondents agreed, then this would point at certain motile patterns as having specific meaning and thus the possibility of using such patterns in contexts where this meaning is relevant. If respondents did not agree, then it would support a contextual dependency of the meaning of motion (as already indicated by previous responses).

The goal was not to assess respondents' ability to associate correctly. ”Correctly” understood as: in accordance to the four materials used for inspiration.

Expectation The expectation was that respondents would not agree.

Results

Motile pattern	Semantic value (material)							
	Metal	Rubber	Paper	Sponge	Other	Total(MP)	None	Total
1. Metal	37	39	8	23	19	126	62	188
2. Rubber	23	46	11	28	22	130	58	188
3. Paper	16	66	10	24	8	124	64	188

4. Sponge	13	54	4	39	19	129	59	188
5. Neutral	31	51	8	21	9	120	68	188
Total(SV)	120	256	41	135	77	629	311	940
	19%	41%	6,5%	21,5%	12%	100%	-	-

Comments The following nine comments apply to both Q7 and Q9:

1) Q7 and Q9 develop the tendencies observed in Q3 and Q5 and require respondents to not look for a specific trait, like ”sluggish” or to state preference. In these questions the respondents are asked to associate the individual motile patterns to specific material (Q7) and affective values (Q9), or answer none.

2) The material and affective values are referred to as semantic values. The meaning of these values is dependent on the individual respondents pre-understanding. The meaning is open-ended.

3) The association of semantic values and motile patterns depend on many factors, but the decontexualised nature of the exercise should have created a focus on movement as the dominant associative stimulant. However, at this point in the questionnaire the respondents would probably have generated an idea about the focus of the study. The semantic values enforce existing associations, inspire associations, or neither, hence the option None. The reported experiences are therefore a combination of the respondents pre-understanding, expectations, the appeal of the semantic values, and the interactive sensomotoric experience (via recall, or revisit) of the objects during the exercise.

4) No percentages are provided as totals have two dimensions: Motile pattern (rows) and semantic value (columns). In the questionnaire the circles were presented as Circle 1, circle 2, etc..

5) Due to the randomization of motile patterns in the exercise, then the subsequent sorting and compilation into one table also separated the responses from the possibility of creating meaningful tabulations. However, the distribution of responses in Q7 and Q9 do not indicate any particular patterns that require insight into the respondent group. In support of this is also lack of tabulations for prior questions revealing any bias affecting responses.

6) The values in column Total(MP) indicate how many times a motile pattern (rows) has been selected as ”some material/some characteristics” by respondents: how many times this motile pattern has created material/affective associations. E.g. the metal pattern was believed by 23 respondents to mimic the material sponge; and metal pattern was in total chosen 123 times to mimic one of the five material values (including other). I refer to the values in the rows as ”pattern matches”.

7) The values in row Total(SV) indicate how many times a semantic value (columns) has been selected as associated to a motile pattern: how many times a respondent has chosen to associate the material/characteristics to a motile pattern. E.g. the semantic value metal was chosen 13 times to be represented by the sponge pattern; and in total the metal value was chosen 120 times to describe one of the five motile patterns. I refer to the values in the columns as ”semantic matches”. Percentages are provided for Total(SV).

8) None is not included into Total(MP) and Total(SV) as these responses indicate that the respondent did not have any associations. None of the motile patterns have generated particularly more none-answers than the other patterns: For Q7 the average is 62 nones within a range of 59-68 (median 62), and for Q9 the average is 32 nones within a range of 29-36 (median 32).

9) The response-profile for Total(MP) indicates that none of the patterns have been particularly un-associative, or ”non-matching” as all patterns receive fairly similar number of responses. The average for Q7 is 126 responses in a range of 124-130 (median 126), and the Total(MP) average for Q9 is 156 responses in a range of 152-159 (median 156). The interesting question is therefore which semantic values the respondents associated to which motile patterns?

Comments on Q7 responses:

The semantic values presented to respondents (columns) matched the material references used as inspiration when designing the objects. Respondents had no knowledge of this connection. These semantic values for material reference were maintained as they throughout the study design had received no comments as being unknown to those involved in the various design activities. The overlap in mapping also enabled an assessment of whether respondents did actually recognise the ”source”. A positive identification would connect the understanding of material motile patterns by the group of respondents to that of those involved in the design activities. Thus the question established basis for patterns of agreement among both respondents and among respondents and people outside the respondents group.

Rubber is by far the most popular semantic value. In total rubber was selected 256 times equaling 41% of total responses. These 256 responses are fairly evenly distributed across all 5 motile patterns: Paper pattern receive the most ”votes” by 26%, sponge pattern 21%, neutral pattern 20%, rubber pattern 18%, and metal pattern receive the least: 15%. These numbers show that no particular motile pattern appeal to the respondents association of rubber. All motile patterns have been associated to rubber and the distribution of association among patterns is quite even. Patterns paper and sponge being those with the highest semantic popularity for mimicking rubber. Pattern rubber occupies the fourth place which shows that this pattern, by the respondents evaluation, is not the best at mimicking their idea of rubber. Pattern paper receives the highest semantic match (matching value to pattern) for rubber with 66 unique votes (26%). This is the highest overall number of votes for a semantic match and border on the 20% which would be the even distribution among all five motile patterns. The semantic match is therefore not significant.

The other four semantic values, metal, paper, sponge and other exhibit a distribution of semantic matches across all five motile patterns similar to that of rubber. In no instances do the votes for a semantic value single out a specific motile pattern as particularly popular.

The metal value receives 19% of the Total(SV). The metal value has the most votes for pattern metal (31%) and thus exhibits a semantic match between the same value and pattern. The second highest number of votes is given to pattern neutral (26%) and the least to pattern sponge (11%). The tendency is that the least reactive patterns are associated to the semantic value metal. The remaining 32% votes are given to patterns rubber and sponge. There is no distinct semantic match for the metal value.

The paper value receives the least share of Total(SV) (6,5%) which could be due to a lack of knowledge among respondents of how a ”paper circle” moves. Thus association to the paper value has not been an immediate reaction. The paper pattern received 10 votes, which is the second highest score. In comparison are the 8 votes for pattern metal which exhibits somewhat different motile properties (Table 5). It appears that the semantic value does not make much sense: very few votes and no consistency.

The sponge value has the second highest share of Total(SV) (21,5%). Like value metal, then value sponge has the best semantic match (29%) between the same value and pattern. However, less reactive patterns like metal and neutral account for 33% of semantic matches and rubber and paper the remaining 21% and 17%. The votes are so diverse that none of these semantic matches have any significance.

Semantic value other receives 12% of Total(SV). When respondents have not found any semantic matches among the four proposed values (metal, rubber, paper and sponge), then patterns paper and neutral have generated the least alternative associations (10% and 12%) whereas patterns metal, rubber and sponge have generated the most (25%, 28% and 25%). This seems to identify patterns paper and neutral as the motionally least significant and patterns metal, rubber and sponge better at generating associations to materials known by the respondents, but not represented.

For each semantic value the highest scoring matches are as follows*:

1. Rubber = Paper pattern – 66/256 votes – 26%

2. Sponge = Sponge pattern – 39/135 votes – 29%

3. Metal = Metal pattern – 37/120 votes – 31%

4. Other = Rubber pattern – 22/77 votes – 28%

5. Paper = Rubber pattern – 11/41 votes – 27%

* by number of votes as the percentage is relative to the Total(SV) for each value.

This overview have patterns paper, sponge, metal and rubber represented, but not neutral. This does not identify neutral as unpopular as neutral overall only received 10 votes less (120 Total(MP)) than the most popular pattern rubber (130 Total(MP)). The overview does show a tendency of discernment among the patterns as each semantic value points to a different motile pattern as the most significant. In two cases it is the same as originally used as inspiration (sponge and metal). Finally the overview highlights pattern paper as the most popular semantic match.

The following overview of pattern matches answers the question: did the respondents "recognise" the motile patterns as the material originally used as inspiration? However, obtaining this match was not the intention of Q7. The overview present the highest scoring match for each motile pattern:

1. Paper = Rubber value – 66/256 votes – 26%
2. Sponge = Rubber value – 54/256 votes – 21%
3. Neutral = Rubber value – 51/256 votes – 20%
4. Rubber = Rubber value – 46/256 votes – 18%
5. Metal = Rubber value – 39/256 votes – 15%

The result confirms that the rubber value, to respondents, stood out as the most associative value. Rubber was the only motile pattern that got the best pattern match from the similar semantic value, but not the best score for a pattern match.

The 41% of Total(SV) for semantic value rubber stand out as this is almost twice as many as value sponge receiving the second most votes (21,5%). Why this many semantic matches for rubber? The distribution of matches is fairly even across the five motile patterns, so the popularity could be due to the associative power of this semantic value. Comparing to Q9 might explain this. The most popular semantic value in Q9 is lively with 31% of Total(SV). The most popular semantic match for lively is pattern paper with 27% (65 votes). For semantic value rubber the most popular pattern is also paper with 26% (66 votes). In both Q7 and Q9 then this score by pattern paper is the best for semantic match. By the values described inTable 5, paper is probably the most reactive object version and therefore stands out. In Q3 (ID of neutral version), paper pattern is located in the lower third and thus does not come across as particularly neutral, which supports an experience of reactiveness. In Q5 (like/dislike) paper pattern scores 21,5% of likes and is in the top 50% (2nd place) and scores 18% dislikes and is in the lower 50% (3rd place). From these numbers pattern paper stands out as fairly popular and as a motional contrast to neutral. In relation to understanding the popularity for semantic value rubber, then rubber and lively share the high score for paper, which seems to be a pattern noticed by most respondents. This overlap in semantic matches is also present across the other patterns when comparing values rubber and lively: Pattern metal scores 39 for value rubber and 24 for value lively (this is the worst overlap), pattern rubber scores 46 for value rubber and 43 for value lively, pattern paper is 65 – 66, pattern sponge is 54-60 and pattern neutral is 51-49. The score profiles for the two semantic values almost match and the total(SV) is therefore also almost identical (256-241). None of the other semantic values compares score profiles this well. The point is that semantic value rubber by the profile match to semantic value lively is given exactly this description: Respondents' idea of "a rubbery material" is lively. However, as the semantic matches are as distributed as they are, then conclusion is also that respondents do not agree upon what motile properties describe lively. The paper pattern is the closest we get.

This finding relates to the responses provided in Q7, part 1, where 65,5% of respondents report touchscreens as "dynamic and full of movement", and Q8, part 1 which establishes an overall positive approach to touchscreen interaction and the bodily and dynamic nature hereof.

In Q4 58% reported that they found the patterns mimicking a material. 12% reported don't know and 30% no. This amount of negative answers is similar to the amount of negative answers reported for this question where the number of respondents answering none average 33%.

It has been established that semantic value rubber is by far the most popular because it is lively, but no agreement on what lively is. Motile pattern paper is the best candidate. There is a tendency for discernment among the motile patterns, but no significant semantic matches have been identified. The best match is value metal matching pattern metal with 31% of the Total(SV) for value metal. The general insight is that no consistent semantic matches appear as respondents, when deprived of any other references than motion, do not agree on which semantic material value to ascribe to the motile patterns.

These results demonstrate how the abstract system model illustrates the dynamics of Figure 16 by neutralising all four parameters and only presents one primary associative component (movement) and thereby apparently produce very different experiences for users (respondents). Even in the simplistic incarnation of the exercise, these factors create a dynamic for instilling different experiences, different meanings. All respondents experiences of materiality are correct, but based only on their individual understanding of the motile patterns. This also means that the meaning of a motile pattern in a real system context is wholly a product of the four factors within this system context as discussed in connection to Q5. It also means that the functional animations embedded into a system context may reference some common ideas of e.g. rubbery being lively, but the overall understanding and accept of a functional animation component is a product of how well it supports the tool, task and users' conceptual model hereof. The motile pattern will be a product of the functional purpose. It will be a designed component within a larger semantic system. The meaning ascribed to the motions by users will not be their material associations, but their support for task completion. The meaning will be contextual.

12.17 Part 2, Q 8, Obligatory: Actions creating material association

Question *Did any of the below actions lead to the impression of one or more versions of the circle resembling a MATERIAL?*

1. Push/Pressure
2. Pull
3. Collision
4. Release
5. Flick
6. Slide
7. Rebound
8. None
9. Don't know

Rationale This rationale also applies to Q10 in relation to Q9.

The question follows up on Q7 by requesting the respondents reasons for associating the motile patterns to certain materials. This question should have been asked for each motile pattern in Q7. But asking for motile properties, as done in Q4, would require the respondents to analyse the motile properties of each motile pattern in relation to their associations. This was too abstract, too cumbersome, and would exhaust the respondents into a negative mode of participation.

A general mode where the sub-questions ask for indicative actions was therefore established. The responses will indicate whether any actions stand out for creating associations about the semantic value of the motile patterns.

Expectation No particular expectations.

Results

Impact	Pull	Rebound	Slide	Press	Release	Flick	None	Don't know	Total
107	92	77	57	49	42	42	13	26	505
21%	18%	15%	11,5%	10%	8,5%	8,5%	2,5%	5%	100%

Comments Respondents were asked to indicate those actions that provided the experience of materiality. The table is ordered by descending values.

54% of responses establish actions impact, pull and rebound as the prominent actions for understanding the motile patterns. What happens upon press and release seem to have less importance. The 42 responses for action flick (8,5%) does not correspond to the only 16 respondents confirming the objects to be flickable in Q4.

The query approach – asking about actions, point to a particularity about movement in the interactive setting: in this context movement is either a reaction to an event (user or system originated) or itself a cause for a reaction. Movement is both cause and effect. E.g. impact and rebound are both the results of an object moving into something. Pull, slide and flick are reactions to user gestures affecting the object. This also indicates a transgression between users' bodily movement and a corresponding motile effect in the digital object. The body movement connects directly to the motile reaction as a cause for this. Similarly for press and release, but these are not movements of, but inert movements and therefore apparently receive less attention by respondents. So are impact and rebound but these actions are probably more dramatic as they signify lack of control and therefore get attention. This also explains why impact, pull and rebound are the prominent actions for identifying the motile properties, differences and associations.

12.18 Part 2, Q 9, Obligatory: Affective association

Question *Did you experience one or more versions of the circle as exhibiting a certain CHARACTERISTIC?*

Rationale For this question the respondents are asked to provide an affective semantic match. The rationale is the same as for Q7.

Expectation The expectation was that respondents would not agree.

Results

Motile Pattern	Semantic value (characteristica)							
	Kind	Annoying	Apathetic	Lively	Other	Total(MP)	None	Total
1. Metal	34	29	65	24	4	156	32	188
2. Rubber	32	31	45	43	8	159	29	188
3. Paper	37	26	16	65	8	152	36	188
4. Sponge	31	28	17	60	19	155	33	188
5. Neutral	57	16	30	49	5	157	31	188
Total (SV)	191	130	173	241	44	779	161	940
	24,5%	17%	22%	31%	5,5%	100%	-	-

Comments Comments on how to read the data are listed at Q7.

The 4 affective characteristics were established as two contrasting pairs: Kind – Annoying and Apathetic – Lively.

The results of Q9 are similar to those of Q7: Respondents do not agree on semantic matches. But for Q9 the distribution of responses in relation to Total(SV) is more even than for Q7 which had value rubber stand out with 41% of Total(SV). For Q9 the highest total(SV) is value lively with 31%. This is followed by kind (24,5%), apathetic (22%), annoying (17%), and other (5,5%). The below overview list the most popular semantic matches*:

1. Apathetic = Metal pattern – 65/173 votes – 38%

2. Lively = Paper pattern – 65/241 votes – 27%

3. Kind = Neutral pattern – 37/191 votes – 30%

4. Annoying = Sponge pattern – 22/130 votes – 24%

5. Other = Sponge pattern – 11/44 votes – 43%

* by number of votes as the percentage is relative to the Total(SV) for each value

The match of value apathetic to pattern metal stands out as the overall highest number of votes across both Q9 and Q7. The match between lively and pattern paper has been discussed at Q7. Value kind is assigned to pattern neutral which has no inert motile properties and only a minimum of movement. This of course indicates what kind means – at least in this motile context. Both annoying and other have the most votes for pattern sponge. The following overview of pattern matches present the most best match for each motile pattern:

1. Metal = Apathetic value – 65/173 votes – 38%

2. Paper = Lively value – 65/241 votes – 27%

3. Sponge = Lively value – 60/241 votes – 25%

4. Neutral = Kind value – 57/191 votes – 30%

5. Rubber = Apathetic value – 45/173 votes – 26%

Contrary to Q7, these pattern matches do not point to only one semantic value. Both patterns metal and rubber are matched to value apathetic and both patterns paper and sponge are matched to lively. Neutral is kind. These matches are in line with the descriptions provided in Table 5 and Table 6 which set metal and rubber as not so responsive and paper and sponge as responsive. Similarly to the semantic matches in Q7, these two overlaps in pattern matches indicate a tendency for agreement and recognition among respondents and the original intention, but nothing significant.

Respondents might have felt obliged to choose a value, as this is what they are asked. But considering the number or respondents answering none, then this is probably not the case. The semantic values (including other) on average received 156 responses and 161 respondents answered none. This almost even popularity indicates that respondents have probably not felt obliged to pick a semantic value. This is supported by Q7 where 311 respondents answered none. However, this is also more than twice as high as the Q7 Total (SV) average: 126. Comparing the totals reveal that Q9 received 150 more answers than Q7 (629 vs. 779). This discrepancy, and the many none answers for Q7, could indicate that describing the objects by affective association is easier, or more appealing than comparing it to a concrete material. The affective descriptors are probably closer to the personal nature of the experience and thus elicit more answers. Maybe also better answers. This indicates what type of vocabulary to use for describing motile patterns. They might be inspired by materials, but e.g. for evaluation, affective descriptors are best. This is supported by the 5,5% selecting value other for Q9 and 12% selecting other for Q7 – the affective semantic descriptors appear to have been easier to apply and have elicited more responses.

Methodologically, then the increase in responses from Q7 to Q9 indicates that respondents have not become disengaged from the survey at this point. This adds validity to the answers.

12.19 Part 2, Q 10, Obligatory: Actions creating affective association

Question *Did any of the below actions lead to the impression of one or more versions of the circle to exhibit a certain CHARACTERISTIC?*

1. Push/Pressure
2. Pull
3. Collision
4. Slip
5. Flick
6. Slide
7. Rebound
8. None
9. Don't know

Rationale See Q7.

Expectation No particular expectations.

Results

Pull	Impact	Rebound	Slide	Release	Press	Flick	None	Don't know	Total
102	86	64	63	46	44	40	7	36	488
21%	17%	13%	13%	10%	9,5%	8%	1,5%	7%	100%

Comments Respondents were asked to indicate those actions that provided the association of a characteristic. The table is ordered by descending values.

Compared to Q8, then the order of priority is almost the same only impact and pull swap place and so does press and release. The values are very similar and the overall pattern is the same.

The results for Q8 (material) are provided in descending order for comparison: Impact (21%), Pull (18%), Rebound (15%), Slide (11,5%), Press (10%), Release (8,5%), Flick (8,5%), None (2,5%), and Don't know (5%). The total number of respondents is a little smaller than Q8 total (505).

The consistency in reporting causes for experience indicates that the experience of the objects have taken hold within the respondents. Two different evaluative questions (Q7 and Q9) about the same objects does not change the objective descriptions hereof. The object experience is resistant.

12.20 Part 2, Q 11, Not obligatory: Relation betw. circles and courses

Question *The below statements concern the relation between the circle and the courses*

1. I recognised the different versions of the circle across the 3 courses

2. The layout of the 3 courses helped me identify more versions of the circle

3. One or more versions of THE CIRCLE AFFECTED my impression of the COURSES POSITIVELY

4. One or more versions of THE CIRCLE AFFECTED my impression of the COURSES NEGATIVELY

5. My experience of one or more versions of the circle CHANGED IN A POSITIVE DIRECTION during the courses

6. My experience of one or more versions of the circle CHANGED IN A NEGATIVE DIRECTION during the courses

Rationale This question addresses context to get insight into 1) whether the courses affected the respondents experience of the objects, and 2) whether the objects affected the experience of the courses.

Expectation No particular expectations.

Results

Sub-question	Yes		Neutral		No		Don't know		Total
1. Recognise	138	73,5%	22	12%	20	10,5%	8	4%	188
2. Layout	106	56%	34	18%	33	18%	15	8%	188
3. Pos. effect	91	48%	47	25%	30	16%	20	11%	188

4. Neg. effect	87	46%	41	22%	43	23%	17	9%	188
5.Pos. direc.	71	38%	48	25,5%	48	25,5%	21	11%	188
6. Neg. direc.	61	33%	50	27%	55	29%	21	11%	187

Comments A challenge for this question was to not reveal that there were in fact different object versions, while asking whether the courses affected the experience of these versions. Also the sub-questions had to be brief, no too many, and not too detailed, and of course precise and unambiguous. For these reasons the question did not address the courses individually.

Sub-question 1 addresses the respondents ability to recognise the different versions across the three courses. The majority of respondents (73,5%) resport recognition across courses. 12% are neutral. 10,5% answer no and 4% don't know. This establish that the identification of different versions and thus the meaning of motion is persistent even under different circumstances. The no and neutral groups do not exhibit any particular bias.

Sub-question 2 addresses the layout of the courses. By layout is meant the positioning and amount of obstacles. 56% confirm that the layout helped them identify more versions of the circles. In Q8 and Q10 just above 50% pointed to actions pull, impact and rebound as important in identifying the semantic values. These actions are a result of the task and the courses. Pull is necessary to move the object (if not flicked) and impacts and rebounds are caused when respondents steer the object into the obstacles. Q11, Q8 and Q10 therefore support one another in identifying the context as important for identifying the object differences.

Sub-question 3 and 4 address the objects' effect on the respondents' positive/negative impression of the courses. The overall response distribution profile is fairly similar between positive and negative effect. 48% report positive and 46% report negative effect of the circles upon the experience of the courses. In principle, the respondents answering yes to positive effect, could also be among those answering yes to negative effect. The questions are not mutually exclusive and an overlap would reveal reflection among respondents and thus validation of their responses. 69% of those 91 respondents answering yes to positive effect also answered yes to negative effect. 19% of the 91 answered no to negative effect. The no groups show similar patterns of overlap and the neutral group has almost 100% overlap, but also a few yes and no responses. From the responses it seems that the objects did affect the individual respondents' experience of the courses in both positive and negative directions. E.g. the neutral object is easy to use if a steady pace is held, and it does not deform upon impact. This could be good for the labyrinth course. Whereas the open space course could challenge the calmness of the neutral object as there are no obstacle to negotiate and thus the slow speed required by the neutral object would give a negative experience of the course.

From a questionnaire design perspective, then sub-question 3 and 4 should have been located as the last questions as sub-questions 5 and 6 return to the focus of sub-question 1 and 2: the courses effect on the object experience.

Sub-question 5 and 6 address the positive/negative effect of progressing through the three courses upon the object experience. The overall response distribution profile is fairly similar between positive and negative effect. 38% report positive and 33% report negative effect. Similarly to sub.-que. 3 and 4, then a pattern of overlap is present between those reporting yes to both negative and positive, and for those answering no, neutral and don't know. Again the respondents appear reflective. The responses are primarily neutral (25,5% & 27%) and negative (25,5% & 29%) The no's could indicate that the experience of the object profiles has been established during course 1. Course 1 is the most complex in terms of navigation and negotiation of obstacles and thus provided a nuanced foundation for experiencing the objects. The yes-respondents must have benefitted from the progression and variety of courses in getting to know the objects. This indicates that evaluations via only a single instantiation of a task will not (necessarily) produce a correct result as understandings are products of several interactions.

12.21 Part 2, Q 12, Not obligatory: Relation betw. circles and exercise

Question *The below statements concern your impression of the exercise*

1. I think the exercise was difficult
2. I was aware that I was using a touchscreen
3. I was aware that the exercise was executed on digital technology
4. I felt like playing with one or more versions of the circle
5. One or more versions of the circle were annoying
6. One or more versions of the circle were too sluggish for the exercise
7. One or more versions of the circle were too lively for the exercise
8. It felt natural to use my fingers for the exercise

Rationale This question addresses the exercise itself and the relationship between the exercise and object experience.

Expectation No particular expectations.

Results

Sub-questions	Yes		Neutral		No		Don't know		Total
1. Difficult	2	1%	13	7%	170	91,5%	1	0,5%	186
2. Touch	56	30%	18	10%	108	58,5%	3	1,5%	185
3. Aware	37	20%	28	15%	117	63,5%	3	1,5%	185

4. Playful	37	20%	28	15%	117	63,5%	3	1,5%	185
5. Annoying	151	81%	15	8%	17	9%	3	1,5%	186
6. Sluggish	154	83%	9	5%	19	10,5%	3	1,5%	185
7. Lively	50	27%	23	12,5%	110	59%	3	1,5%	186
8. Fingers	178	95,5%	6	3,5%	-	-	2	1%	186

Comments Sub-question 1 establishes that none of the respondents found the exercise difficult. This establishes that the objective of simplicity was fulfilled and that answers have not been affected by difficulties in understanding or performing the exercise.

Sub-question 2 addresses the interaction modality framing the exercise. Only 30% report awareness of the touch modality. 10% report neutral and almost 60% report that they were not aware. No variables identify any bias for these answers. The respondents do in general exhibit a positive attitude, experience and frequency of touchscreen use (Q3-8, part 1), so these answers are in line with these perspectives. Performing actions in this environment therefore comes ”natural”. The yes answers might be due to the study context and explicit focus on touchscreens.

Sub-question 3 addresses the respondents’ awareness of ICT in the exercise context. Only 20% report awareness and 63,5% report no and 15% are neutral. Tabulating to Q4, part 1 where 71,5% reported: awareness of using digital technology, then 84% of the 20% reporting awareness also reported awareness in part 1, Q4. However, 66% of those answering no in the present question also answered yes in Q4, part 1. Of those answering neutral for the present question 79% answered yes in Q4, part 1. The question does not make a lot of sense, and the inconsistent answers underlines this.

Sub-question 4 asks whether respondents felt like playing with any of the objects. This follows up on Q8, part 1, sub-que. 7 where 68% of respondents were positive towards this notion. Similarly to sub-que. 3 above, then the responses from the first incarnation of the question (Q8, part 1) are not entirely consistent. Those answering yes in Q8, part 1 are distributed across both, yes, no and neutral for this question. No other variables reveal any significance for the respondents of this question. It could be suspected that answers for this question are more correct than those for Q8 as this question addresses a concrete situation.

Sub-question 5 and 6 exhibit almost similar response profiles when asking whether any objects were annoying or too sluggish for the exercise. The majority of respondents answer yes. Sub.-question 6 position the object experience in relation to how well they worked for the exercise. In Q3, part 2 just above 90,5% of respondents reported one or more objects as sluggish or inert. This experience of sluggishness is established as a factor of the exercise usability by the positive responses for these two sub-questions. Between 80 and 90% of respondents find one or more of the objects too slow for completing the exercise. ”Too slow” understood as in relation to how fast they would expect to complete the exercise if objects behaved differently. As discussed during Q11, then this experience is relative to the task and the context.

Sub-question 7 asks whether any objects were experienced as too lively for the exercise. 59% do not find any object versions too lively for the exercise. 12,5% are neutral and 27% do find some versions too lively for the exercise. No variables identify any bias for these answers. Tabulating the answers from sub-questions 5 and 6 reveals the previously seen overlap between those answering yes to too sluggish also answering yes to too lively. The overlap is 96%. Again, this reflection validates the answers and underline how the experience of motion is a factor of the four elements of interaction design.

Sub-question 8 reiterates question 8, part 1 by asking for respondents’ feeling of naturalness about using their finger for the exercise. 95,5% confirm this and no-one answers no. This overwhelming confirmation could be due to the respondents extensive touchscreen experience and thus a feeling of naturalness in interaction ”as usual”. The modality has been learned and now feels natural.

The answers validate the methodological intention of the exercise and establish insight into how the relationship between exercise and objects have been a factor in the respondents’ experience of the objects.

12.22 Part 2, Q 13, Not obligatory: Answering process

Question *How did you reach your answers?*

1. Did you return to the exercise and try again?
2. If yes, did this then change your impression of one or more versions in a POSITIVE direction?
3. If yes, did this then change your impression of one or more versions in a NEGATIVE direction?
4. If yes, did this then change your impression of the number of versions of the circle?

Rationale Knowing whether respondents reached their answers based on first impressions or returned and investigated their recollection was important as the study should not test memory.

Expectation Some respondents would go back, but not everyone as returning would also require a commitment to the questionnaire that could not be expected from all respondents.

Results

Sub-questions	Yes		No		Not relevant		Total
1. Return	111	59%	74	39,5%	3	1,5%	188
2. Pos. direction	55	29%	61	32,5%	72	38,5%	188

3. Neg. direction	79	42%	30	16%	79	42%	188
4. Versions	26	30%	26	30%	35	40%	87

Comments 59% of respondents returned to the exercise. 29% of these report a change in impression of the objects in a positive direction. 42% report a change in a negative direction. The use of positive and negative is ambiguous, but sub-question 4 asks respondents who answered yes in sub-question 2 and 3 to report whether this changed their impression of number of versions of objects. 30% report change and 30% report no change. 40% answer not relevant to sub-question 4. Of those that report change in number of versions if they went back (sub-que. 4), then a few actually did not go back (tabulating to sub-question 1). Tabulating sub-question 4 with sub-question 2 and 3 reveal that a small majority made impressions in a positive direction, but some of those reporting changes in positive direction also report not making any changes when going back. The same pattern is present for those reporting impressions in a negative direction and also reporting changes when going back. The implications of these behaviours in answering the survey have been unfolded in connection to Q2.

Sub-question 4 was added late in the data-collection process. This could be done because of the dynamic on-line approach established by Google Forms embedded into the App-environment.

12.23 Summary survey Part 2

Question 1 confirms the research question and hypothesis (section 9) as more than 90% report experiencing 2 or more objects. The following questions looked into the details of this experience and revealed that no consistent patterns of experience are present among respondents. Respondents experience a fairly high degree of difference among objects and identified 3,4 objects on average (Q3) which indicate a sensibility to movement as an independent, meaningful and significant design component. To set the versions apart respondents consistently report motile properties *movement of* and the inert motile property *reaction* due to actions impact and rebound. These clear indications of movement as semantic signifier also indicate that movement instills meaning independently of other associative elements like graphics and audio that were not available as signifiers in the exercise.

The study did not aim at identifying certain motile patterns as significant of anything, but the study represented an opportunity to explore the respondents' understandings of these motile patterns. This exploration revealed that respondents did not agree upon *what* they experienced. The image of the duck-rabbit (. 20) is used to symbolise this variant in respondents' evaluation and characterisation of the five objects. The dispersement of responses is surprising and no real patterns among responses appear. In Q5, part 2 the respondents are in complete disagreement of preference and when asked about material resemblance and characterisation in

Q7and Q9, part 2 then no significant semantic matches between any motile pattern and a semantic value are manifest.

An increase in responserates from Q7, part 2 to Q9 indicates that these affective semantic values have been easier for the respondents to apply and thus an indication of which vocabulary to use for motile patterns within functional animation.

The questions at the end of part 2 establish that the identification of different versions and thus the meaning of motion is persistent under different circumstances and that these circumstances are part of understanding the object properties. These questions also establish how the interaction between object and courses affects the impression of the courses. The relationship is reciprocal.

None of the answers appear to have any bias in relation to the demographic and ICT variables established during the questionnaire part 1. 59% of respondents used the opportunity to revisit the exercise to evaluate the basis for their responses. This behaviour support the validity of study data as respondents must have felt secure about their experience either by actually returning, or by awareness of this possibility. The behaviour also validates movement as a meaningful phenomenon since respondents only had movement to evaluate upon when going back, and this behaviour has felt meaningful as they knew how to look for difference: motile patterns.

The study seems to verify J. J. Gibsons theories of visual perception (Gibson, 1979) as the responses clearly show how the experience and understanding of difference among objects is formatted not only during interaction between object and user, but also between object and environment. The respondents thus use the environment to explore and format an understanding of the objects and vica versa understand the environment properties via the object. Adding to this is an understanding of how to manipulate one's own body to manipulate the object. The object thereby also affects the respondents' understanding of own capabilities. A possible novelty of this study is this verification of Gibson's theory in this digital touchscreen environment.

There is some redundancy in the questionnaire. E.g. sound and colour are addressed three times and motile properties are also addressed three times. However these redundancies also validate one another and the purpose of asking is different each time. From the responses it generally seems as if respondents have answered with consideration and commitment. The redundancies do appear to have had a negative effect on the responses.

Some sub-questions are ambiguous. These instances are discussed during the comments for each question and the ambiguities do not affect the overall result of the study.

The exercise and progression of the questionnaire appear to have worked as intended in terms of producing valid and reliable results.

Overall then the study positions movement as an effective and thus important design component in relation to interactive digital (touch) systems. Movement should be used discreetly as motile patterns are easily perceived, and do not need other associative stimulants to have an effect. The study constitutes an empirical foundation for understanding movement as an independent component for interaction design and thus the study presents a basis for existing and future studies of functional animation.

13 DISCUSSION

This section discusses three publications on functional animation that were also part of the literature review in order to add detailed perspectives on my study. This is followed by a discussion of the study in a methodological perspective. I will refer to the study presented in Part II as ”my study”.

13.1 Recent and similar research

The publications are selected because they represent recent research contributions to the area of functional animation and because they in different ways relate to my study. I will discuss the publications in no particular order.

”The Communicative Functions of Animation in User Interfaces” by Novick, Rhodes and Wert (2011) is included because this conference paper does exactly what I did not want to do initially: sample existing implementations and deduce general principles of functional animation from this material.

”Kineticons: Using Iconographic Motion in Graphical User Interface Design” by Harrison, Hsieh, Willis, Forlizzi and Hudson (2011) is a conference paper that reports a study which at a more concrete level does the same as my study does in questions 7 and 9, part 2 in terms of trying to make semantic matches between motile patterns and use scenarios.

”Investigating the Affective Quality of Motion in User Interfaces to Improve User Experience” by Park and Lee (2010) is a conference paper which investigates the affective dimension of movement and does so partially via an abstract and interactive system model.

Both Novick, Rhodes and Wert (2011) and Harrison, Hsieh, Willis, Forlizzi and Hudson (2011), present a review which is in line with research questions no. 4 and 5 (section 7) about the proliferation of principles and lack of framework. The aim of research on principles and guidelines for functional animation is to identify the motile patterns that match the requirements of specific system contexts. This represents a two dimensional challenge: 1) to document (all) system events, states, features, etc. and have them represented by movements, and 2) to identify and define generic movements that precisely communicate specific system events, states, features, etc. A schematic of this generic relationship between movement and system context is illustrated in Figure 20. The columns, *motile pattern*, represent the expressive dimension and the rows, *system context*, represent the functional dimension. Where columns and rows converge is where functional animation appears as *a motile form with a functional purpose and effective effect*.

Motile pattern

System context		**X**	**Y**	**Z**
	A	Motile form with effect	…	…
	B	…	Motile form with effect	…
	C	…	…	Motile form with effect

Figure 20. Abstract schematic of the desired identification of connection between movement and system context.

The aim of Novick et al. is to create a generic model of functional animation that relates motile patterns (change of place, size, color and shape, gesture[23], rotation, and blur (Novick, Rhodes & Wert, 2011, p.4)) to system contexts (different context, value, status and function, importance/urgency, reference, and salience (Novick, Rhodes & Wert, 2011, p.4):

> In this paper we claim that the key communicative functions of animation in user interfaces can be characterized by a model that relates the purpose of the communication to the nature of the animation. Such a model could support designers who seek to use animation to expand the effectiveness and usability of user interfaces (Novick, Rhodes & Wert, 2011, p.1).

Novick et al. sample a set of system contexts and corresponding movements that appear representative. Equally to my initial efforts. The difference to my study is the referential independence of abstract system model and the abstract approach to movement. Novick et al. move from the specific towards the abstract whereas my study move from the abstract towards the specific. My study does not reach the specific as the errand is not to identify motion-correctness in relation to system context, but to establish a fundamental understanding of movement as a phenomenon that will have meaning when applied specifically – e.g. in the contexts sampled by Novick et al..

From a theory of science perspective, then Novick et al. take an inductive approach, trying to generate generic rules based on specific examples. And there will be black swans. Within design, then this approach is challenged as the subject of study is also

[23] Novick, Rhodes and Wert (2011) does not explain how gesture becomes a paramter of movement, but does note that his category covers the 6 other categories, which does make it strange to align it with these.

the subject to change by the ”generic rules” created via research of reality. Meaning that, as soon as the rules are applied in practice, then they will affect the practice and ”black swans” will appear.

The movement parameters and system functions (which I refer to as motile patterns and system contexts) are not explained by Novick et al. The process for creating these categores is an ”… exploratory study [of] … GUIs for operating systems, office automation applications, video games, commercial Web sites, proposed future interfaces, and other specialized interfaces” (Novick et al., 2011, p.3). Exploratory means that it is the authors that selected the samples without any explicit selection criteria. The samples are reviewed, by the authors who then distill 7 movement parameters and 7 systems functions. The authors establish a matrix where appropriateness is evaluated quantitatively, by the authors. Based on this evaluation the authors create two prototypes (in powerpoint) that are evaluated, by the authors. In the conclusion Novick et al. explicate an awareness of their subjective research methodology: ”… applying our own judgment, based on traditional Norman-like cognitive models of human-computer interaction, to the examples we surveyed. But this approach necessarily involves the subjectivity of the researchers’ judgments” (Novick et al., 2011, p.7). This subjectivity is not verbalized as a factor that might have created a self-fulfilling research setup and certainly undermines the study reliability. In fairness, Novick et al. identify the challenge of representativeness that made me cancel my initial research activity: ”How should we determine the population of interfaces to sample?” (Novick et al., 2011, p.7), they ask in their conclusion. My answer is: make a study that does not base a typology on samples of existing design, but research the foundations for making these designs. The foundation of functional animation must be that motion in an interactive context is meaningful to the user. This will allow contextual meanings like guidelines and principles to rest and develop on an empirical foundation. A schematic of my study would look like Figure 21.

<table>
<tr><td></td><td></td><td colspan="3">Motile pattern</td></tr>
<tr><td></td><td></td><td>Movement X
e.g. Metal patten</td><td>Movement Y
e.g. Rubber pattern</td><td>Movement Z
e.g. Sponge pattern</td></tr>
<tr><td rowspan="6">System context</td><td rowspan="2">Context A
Task in Labyrinth course</td><td>1. Report experience of X</td><td>…</td><td>…</td></tr>
<tr><td>2. Report experience of X in relation to A</td><td>…</td><td>…</td></tr>
<tr><td rowspan="2">Context B
Task in Open space course</td><td>…</td><td>1. Report experience of Y</td><td>…</td></tr>
<tr><td>…</td><td>2. Report experience of Y in relation to B</td><td>…</td></tr>
<tr><td rowspan="2">Context C
Task in Obstacle course</td><td>…</td><td>…</td><td>1. Report experience of Z</td></tr>
<tr><td>…</td><td>…</td><td>2. Report experience of Z in relation to C</td></tr>
</table>

Figure 21. Illustration of the abstract system model setup for my study.

Harrison, Hsieh, Willis, Forlizzi and Hudson (2011) is a WIMP GUI study. The concept ”Kineticons” is proposed, based on a test of 39 motile patterns (e.g. ”Heart beat”, ”Cartoon Bounce”, ”Spin in”, etc.) in combination with a set of 8 device states and events, or system contexts (e.g. item is opening/loading, item is draggable, item needs attention, etc.). The test covers 39 kinetic behaviours, but ”Obviously the set of possible behaviors and GUI elements to apply them to is limitless” (Harrison et al., 2011, p. 2003). This observation is the same as discussed in connection to Novick et al.: That the cases of application are in principle endless and a generic theory is therefore hard to establish. Like Novick et al., then Harrison et al. seek to create an abstract ”vocabulary” for the description of functional animation (around icons) and to do this they select states and events (based on personal judgement, like Novick et al.) to test as examples of this vocabulary.

Harrison et al. has 200 respondents from amazon.com’s Mechanical Turk, which is a valid number of respondents. However, the study presents the 51 examples via video. 12 examples rendered inside a system context (menu, dialog, and desktop). 39 outside a system context (not explained in paper). Respondents then use a Likert scale to state which of the 8 states and events the movement is representing the most. Figure 22 illustrates the test setup and also illustrates how this compares to the abstract schematic (Figure 20).

		Motile pattern		
		Heart beat	**Cartoon bounce**	**Spin in**
System context	**Item is opening/loading**	Does movement create association to system context?	…	…
	Item is draggable	…	Does movement create association to system context?	…
	Item needs attention	…	…	Does movement create association to system context?

Figure 22. The test setup by Harrison et al. (2011). This also illustrates how the study compares to Novick et al. (2011).

For each motile pattern Harrison et al. asked respondents to evaluate (five point Likert) how well it fit each of the 8 selected system contexts. Apparently the respondents did not have the options ”none” and ”other”.

To test interactivity via video is a fallacy. And to ask respondents to match a probably well known (as all respondents had reported daily use of computers) set of system events and states to these movements (which are presented outside a larger system context) establishes an associative task which draw heavily on users established knowledge and experience with digital systems. Movement was in 2011 widely used in mobile touch and WIMP systems and it could therefore be expected that users had been trained by everyday use and reported recognition based on system experience. If the aim is to identify generic motile patterns that communicate certain generic actions, which may then be applied to interaction design, then this approach will only certify the standards already in the making. This could be why a video-based test of interactivity had positive results. Harrison et al. actually include five Apple iOS and OSX motile patterns and these are by respondents correctly matched to their original meaning. Whether this proves generic value or the formation of a standard via familiarity stands unanswered.

What Harrison et al. does different than Novick et al. (among many things) is that they take an abstract approach to defining the movement types. This works around the challenge of selecting a representative set of examples among the many different digital systems. Harrison et al. take their inspiration from a variety of sources: Biological motion, gestures, organic motion, mechanical motion, physics and natural effects, and cartoon conventions. These are then used as inspiration for the 39 motile patterns in their study. However, the possible motile forms are still infinite. But as inspiration and for structuring the creative activity then this is worth exploring further.

The system contexts used by Harrison et al. are concrete examples of the abstractions presented by Baecker and Small in 1990 (Baecker & Small, 1990). See Figure 23 for comparison. There could be three reasons for this: 1) either Baecker and Small (1990) are too abstract (categories are too open), and thus slightly useless for design in concrete contexts, or 2) they simply nailed the categories in their publication since they are still relevant 20 years later, or 3) researchers need to take a different approach to functional animation than the one illustrated in Figure 20. This has two aspects: One is that studies within functional animation, as per the literature review primarily concern WIMP based GUIs which have not changed conceptual model since incepted by Alan Kay and the Learning Research Group at Xerox Parc in 1973. This would explain why Baecker and Small's categories are still relevant. The other aspect is that interactive digital systems are changing and modalities like touch interaction have gained foothold in the common usage of computer systems.

System contexts

Harrison et al. (2011)	Baecker & Small (1990)	Novick et al. (2011)*
Operation is progressing	Feedback - What is happening ?	Signal different status
Positive/Negative events	History - What have I done ?	Signal different value
Replace/Update	Transition - From where have I come, to where have I gone ?	Signal different context
Entrance	ditto	-
Departure	ditto	-
Launching and Opening	Identification - What is this ?	Signal different function
Ability/ Affordance	Demonstration - What can I do with this ?	Signal referent (pointing)
Needs attention.	Guidance - What should I do now ?	Signal importance, or urgency
-	ditto	Signal salience
No immediate match	Choice - What can I do now ?	-
No immediate match	Explanation - How do I do this ?	-
-	-	-
-	-	*System contexts are not explained by Novick et al., so mapping is a guess

Figure 23. Compatibility of system contexts used by respectively Harrison et al. (2011), Novick et al. (2011) and Baecker and Small (1990). The categories are shuffled for comparison. ”Ditto” means that the category above is repeated to match the categories listed either to the left or right of the ”ditto”.

The system contexts by either study are decided by the authors without reference. Harrison et al. provide explanation to their categories, but no rationale. However, as illustrated by Figure 23, it is validating that the categories of the three studies match each other quite well. But: This match is based on my interpretation. It is somewhat concerning that the categories established by Baecker and Small in 1990 are useful as benchmark. The categories established in 1990 should have been challenged.

To progress research in functional animation, then the system contexts proposed by studies like Novick et al., and Harrison et al. (2011) should be further tested and consolidated by application in practice. But the literature review (section 6) revealed that this connection is not happening. The theory-practice gap opens up and the practice originated texts present their own categories of functional animation (Daliot, 2015).

The examples of Harrison et al. and Novick et al., and own studies indicate that the challenge of generic functional animation (see Figure 20) is near impossible to tackle as the number of solutions is infinite and different people will evaluate the same motile patterns differently as soon as they are liberated from contexts. At the end of their publication Harrison et al. have a couple of conclusions that my study supports:

> None of the positively rated interpretations are significant from each other, primarily due to high variance in participants' estimations of the interpretation strengths (Harrison et al., 2011, p.2007).

This statement comes at the end of a section named ”applicability across GUI elements” and I understand this as a finding similar to mine in Q7 and Q9, part 2 where there were agreement on some semantic matches, but these agreements were not significant and therefore no motile pattern could be identified as significant of some system context. Harrison et al. continue their account:

> The high level result here is that kineticons can successfully generalize across a variety of GUI elements (3 of our 4 designs). However, this does depend on the specific design employed. Even kinetic behaviors that are extremely iconic when applied to some GUI elements, could have even a reverse connotations when applied to a different item. Thus, careful testing and iterative design is a necessity (Harrison et al., 2011, p.2007).

The interesting observation from this comment is the dependency ”on the specific design employed” which adds the aspect of aesthetics to how the motile patterns are understood and experienced within similar contexts, but within different system settings. This indicates that even if generic semantic matches should be identified, then the aesthetics of a specific context will potentially corrupt this match. This adds a concrete dimension to the four elements presented by Markussen (1995) where the *task* element represented both general functional and/or experiential goal and the specific user-system interactions towards achieving this goal. This is illustrated by Figure 24. This illustration differs from Figure 20, Figure 21 and Figure 22 by having added the user goal (outmost right) as this creates the perspective upon understanding and interacting with the system functions. A system aesthetic is added (top row) as ”filter” for all motile patterns as their graphic expression must adhere to this.

		Movement type		
		X	**Y**	**Z**
		System aesthetics		
User goal	**System function A**	**AX** Motile aesthetic and function being experienced by user in relation to goal	…	…
	System function B	…	**BY** Motile aesthetic and function being experienced by user in relation to goal	…
	System function C	…	…	**CZ** Motile aesthetic and function being experienced by user in relation to goal

Figure 24. System aesthetics and user goal included into model of the desired identification of connection between movement and system context (Figure 20).

From this discussion, then functional animation appears as either abstract and detached from context or concrete and attached to context. Harrisson et al. and Novick et al. both tries to get concrete and thus illustrate that the motile possibilites are endless. My study is abstract and does not give any practical guidance on which motile patterns are useful. The question then become: How to provide reliable guidelines for practical use of functional animation? My study has value at the phenomenological level and provides the foundation for doing what is already being done: using movement for designing the interaction with digital systems. The issue then is how not get stuck at the abstract level and not to be so concrete that ”guidelines” are useful only for specific aesthetic incarnations.

I have already suggested that practice is actively involved in studies, but this is only an approach to understand the subject matter and could lead to yet a version the abstract-concrete paradokx. The appraoch must progress and find a middle way between too abstract and too concrete. Practice studies could inform this, but the idea of kineticons presented by Harrison et al. is in line with the generic ambition and point to an establishment of a ”motion gestalt”. Motion gestalts could be motile patterns that within certain parameters determined by Markussen’s four elements (Markusssen, 1995) have an approximate effect or going toward the more concrete end of the spectrum: a catalogue of design patterns (Tidwell, 2010) that addresses various more or less concrete system contexts. This latter is what Harrison et al. attempts. Closed interaction design systems like the interaction concepts of Microsoft, Apple and Google also present solutions to the challenge (Apple Inc., n.d.; Google Inc., n.d.; Microsoft Inc, n.d.)., as they manifest standards at the three concrete levels (skeleton, structure and surface) defined by Garrett (2003). This is an open-ended discussion that will be added to the research agenda for functional animation (section 24).

In opposition to Novick et al. and Harrison et al., then Park and Lee (2010) base their study on user tests of interactive prototypes and they specifically address the affective, not the functional dimension of functional animation.

Park and Lee (2010) reports two connected empirical studies on motion in a WIMP GUI: the first is an empirical test to measure the affective effect of motion on the overall user interface experience in three interactive prototypes. The second is a method to define movements based on human movement qualities as described in the dance notation framework by Laban and Lawrence (1974). I will address only the first study. The conclusion of Park and Lee (2010) is generally in line with those I draw from Harrison et al. and Novick et al.: ”Our analysis shows that motion should be considered as a factor of affective quality in user interfaces. Moreover, the content type and application type requires examination in the user’s perspective to accurately predict the effect of motion” (Park & Lee, 2010, p. 74). User goal (”user’s perspective”), system context (”content and application type”) and system aesthetics (”application type”) all influence how motion is experienced (Figure 24).

Three prototypes represent applications in the study. Two prototypes are similar and mimick a horizontal image carousel allowing right and left paging. One shows football images. The other holiday resort images. The central image is slightly larger than the dimmed neighboring images of which only half is visible to signal more content in this direction, and provides a sensation of depth and curvature. Embedded right/left arrows allow the user to page through the images which then move into focus. The third prototype is contentwise neutral as it only presents a grey circle on a white background (Figure 25) which moves along the horizontal axis when the button is pressed. This interaction pattern is different from the two other prototypes. The three prototypes are rendered with three different movement properties. 9 versions total.

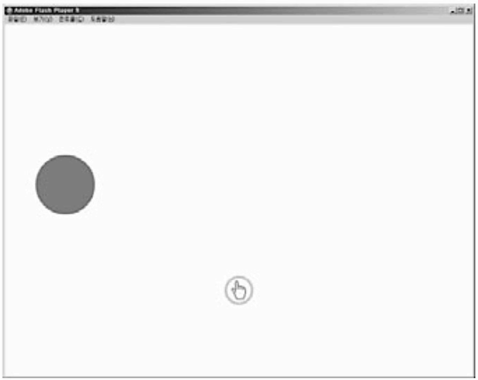


Figure 25. The ”circle prototype” prototype from Park and Lee (2010).

The aim is to generate data on the affective quality of the 9 versions based on respondents evaluation hereof (likert scale) in comparison to 7 preset affective qualities. Question is: How well does the respondent think/feel that a particular version reflects a particular affective quality? The approach is similar to the setup by Harrison et al. where they asked: How well does this movement create association to a particular system context? Only in Park and Lee's setup it is the overall application experience that is evaluated based on the motile patterns and content (images) being different. Park and Lee (2010) wishes to evaluate the affective effect of movement in perspective of both content and application (different images, same three motile patterns for paging). Involving content represents the aesthetic dimension and is not included in neither Harrison et al. nor Novick et al. Park and Lee theorise that content and application might affect the experience of similar motile patterns. They use the word ”application” for their prototypes, but the prototypes are functionally very simple. Jenifer Tidwell (2010) describe the ”carousel pattern” as a variant of the infinite list pattern in a section on how to deal with ”heavy visuals”. I therefore believe it correct to say that Park and Lee are testing the ”Carousel pattern”, which in terms of functional animation could be categorised as a ”transition” (Figure 23). A pattern is a collection if interface components into a specific behaviour. In the case of the carousel, then movement has a significant role as this pattern is designed to literally move images in and out of focus. It is therefore not a surprise that the two image carousels produce very similar responses on affective effect of the three motions: ”Content type showed little significance on how motion influences the affective quality of user interfaces” (Park & Lee, 2010, p.73). Which in the context of the carousel patterns means that the content (the images) did not alter/influence the experience of the pattern functionality. Interacting with football images via movement A creates the same feeling as interacting with resort images via movement A.

The carousel pattern is very similar to the iconic ”cover flow” interaction pattern popularised by release with the Apple iTunes product in 2006[24]. Like Harrison et al. and Novick et al. Park and Lee may very well be testing respondents' experience of an interaction pattern well known from everyday use.

Taking the intended conclusion of Park and Lee, to the outmost consequence would mean that content, or visual appearance, does not influence how the motile properties are experienced. Affective effect of movement should by this account be independent of visual context. Jumping up and down is always happy, not angry. Moving fast is always efficient not hurried. Flattening is always relaxed, not tired. Rigid is always sturdy, not stubborn. The correct conclusion should be that the carousel pattern is a functionally solid pattern that presents different types of content equally no matter how the movement is designed. Movement in this pattern does not affect the experience of the content. But the movement itself might be experienced as having some affective quality as indicated by my study where Q9 showed how similar motile patterns when removed from context are not experienced by any affective consistency.

The ”circle prototype” of Park and Lee is interesting becaue it represents an abstraction that focuses on the motile aspect and not functionality or content. It is, like my study, decontextualised and focused on movement only. Unfortunately, Park and Lee use this prototype to make the respondents initially rate and baseline the affective quality of the three motions, and thus introduce them to the three motile variants via this abstract model. This step teaches the respondents that movement is the subject of the study and primes them for recognising this parameter in the ”image prototypes”. The problem is the same as for Harrison et al.: The research design does not detach the respondents from prior experience. It primes the respondents to look for the seven affective qualities.

The description is somewhat unclear as to how the test is performed, but my understanding is that for each of the six variants of the image carousel, the respondents are asked to report how well each of the seven affective parameters match their experience. This means that for each variant the respondent must evaluate his or her feeling of seven different affective experiences and map it on a 5 point likert scale. The study has good intentions and an interesting theoretical frame, but the experiment does not appear to match a real world situation and in combination with the pre-determined seven parameters (and apparently no options for ”other” and/or ”none”), then it becomes a test of how to satisfy the test. The respondents are 20 students in a laboratory setup

The motile dominance in the carousel pattern, the priming on movement, and likely experience with the pattern, makes the respondents blind to any other parameters than motion which they then map to a finite set of affective parameters because they have no other choice. The validity and reliability of the study is really low, but in

[24] en.wikipedia.org/wiki/Cover_Flow (accessed October 2016).

combination with Harrison et al., and Novick et al. then these studies exemplify how functional animation has been researched in recent years and how my study match this status. Many of the same aspects as included into my study have been addressed. My study should provide the foundation for studies like Harrison et al., Novick et al., Park and Lee and many others who may then e.g. pursue the motion gestalts for interaction design.

13.2 Research method

The discussion of three contemporary research activities has revealed that the approach of my study is on par with other research within the field, both in terms of scope and methodologically. All three studes discussed are also quantitative and the overall aim is to create what I have called semantic mappings – meaningful relations between a motile patterns and some system context. The studies address the subject with various levels of abstraction and scientific rigour, validity and reliability.

An important methodological aspect between my study and those discussed would be the abstraction and de-contextualisation of my study which allow respondents to report their own experience and not map impressions against pre-set categories. Respondents are also removed from any lab-like setting but have complete control of when and why to constribute to the study. Finally, my study is interactive and the experience reported is therefore based on actual actions performed with the subject matter. The test is abstract in content, but concrete in presence. Adding to this are questions reiterating subject and thus ”triangulating” answers and questions asking about the circumstances of the answering process.

My study only had one hypothesis and then became explorative in terms of having no research questions regarding the respondents' experience of the exercise and objects. It is therefore interesting how my results extend some of the insights communicated by in particular Harrison et al. However, I also believe that my phenomenological approach has identified the real challenge in researching guidelines for functional animation and thus creates the foundation for an updated research agenda within functional animation.

A critical perspective would ask: Did the focus on movement in the exercise (by neutralising other expressive components) succeed so well that the exercise is designed to verify the hypothesis ”that motion is meaningful”? Did the exercise by its de-contextualisation represent a portable lab-experiment where any references to a real world scenario did not exist and therefore generated results on a phenomena (motion without meaning) that has no relevance to the research area?

I would think this is not the case as respondents reported different experiences and also reported different experience of the objects' relation to the context and task. The exercise therefore consisted of more than the motile aspect and this aspect was perceived differently. But the study does not contribute with much in terms of providing specific guidelines for functional animation and in that sense the setup is a bit sterile and lab-like.

Does the exercise just emulate an interaction pattern like Park and Lee (2010). Yes, it does, and No, it doesn't. In terms of repeating the same task for all three courses it does, but individual respondents report different experiences of the relationship between task, context and objects and thus it might be the same pattern, but the study, then (contrary to Park and Lee (2010)) shows that these factors do influence the experience of the motile pattern. Adding to this then, the aim was not to test functionality, but to research the experience of motion, and from that perspective, then it is acceptable to repeat the same pattern three times, and a methodological requirement to generate comparable data.

I believe this study has acquired quantitative data on a qualitative subject. The study created a special situation: the exercise which focused on a subjective and qualitative experience and then established a quantitative scheme for reporting this experience without any supervision. The quantitative setup tried to emulate a qualitative setup by allowing respondents to consult their experience by returning to the exercise and verify a feeling or a memory. The respondents therefore did not have to report by memory and hindsight. Also the scheme of reporting did not lock the respondents into a finite set of options as all questions allowed either ”none”, ”other” or ”not relevant”. I believe the dataset to represent a valid expression of the respondents' experience of motion in an interactive digital systems setting.

Quantitative data would have been hard to obtain without an interpretive layer upon qualitative data. The quantitative data in this study are descriptive and provided directly by the respondents, not via a researcher's notes, or annotation of a video or audio file. The self-reporting element and the ability to perform the test in a setting by own choice validate the data provided by this study. The approach to the data in this questionnaire is not to measure or compare for the sake of efficiency, effectiveness or correctness. The study is explorative. The aim is to gain insights into the respondents' experiences, not to judge these against pre-set parameters of right or wrong, high or low within some theoretical framework. The quantitative measures are interpreted in terms of the description of a tendency they provide.

The challenge to this study is the quality of the questions and the ability for respondents to return to the exercise and re-experience and thus change initial impression based on novel experience in combination with a growing idea about the study aim provided by the gradual focus of the questions in part 2. But from the responses in Q13, part 2, then this does not appear to be a problem. The redundancies and ambiguities of questions have been discussed in section 12.23.

A qualitative setup would have required some sort of documentation and possibly the researcher to perform a structured or semi-structured interview to gain insight into the respondent's experience. Such an interview would also have had the element of gradual disclosure of study intend and thus a contamination of the respondent's recollection of experience and impressions. A possible setup could be a think-aloud test (Nielsen, 1993). Comparable data would be dependent on the data-collection and following coding and analysis as mentioned above.

A third alternative would have been physiometric data like eye-tracking or GSR measurement.

A fourth alternative would have been tracking of users' interaction on the device and then an analysis of the motional patterns. I do not possess insight into such methods to evaluate the value for the study subject. But like the qualitative data, it would have to be subject to interpretation. Also an experience is an emotional phenomenon subjective and internal to the respondents, so this is hard to gain insight into from such tracking data. This method would therefore probably work best in tandem with a qualitative method.

In perspective of reliability, then the study setup should be transparent both in terms of intend and replicability. If requested, then the full data set could be made available. Not only to review the validity of my finding, but also to allow other research access and possibility of gaining further insights.

The study does focus on touchscreens as this is the technological platform by which the respondents have established their experiences. I believe the results to apply across other technological platforms too, but this is a belief based on theoretical understandings of the meaning of movement for human experience and not empirical data.

The exercise could be transferred and executed without modification in a keyboard/mouse/touchpad environment. Of course some elements of the questionnaire would have to be modified, but the exercise and the overall focus on identification based on movement-only properties could be replicated.

14 CONCLUSION PART II

The results of the study are quite unequivocal. Motion in the digital touch environment is meaningful to people in a broad sense. And people do not agree on this meaning. The latter is not surprising and an expected result. Meaning is contextual and in this case the context semantics had been neutralised: No significant colours or shapes in either object or environment, no references to known activities.

The study creates a foundation for functional animation and adds a new empirical foundation to the rationales for functional animation in studies like Chang and Ungar (1993) and Thomas and Calder (2001), summarised in Bertram (1997) and extended by Eikenes (2010). I will get back to the existing rationales in section 18.3 when addressing research question no.3.

Methodologically then the study shows that it is possible to perform phenomenological research via quantitative methods. Movement is explored as an independent phenomenon and meaningful, comparable and subjective, empirical data is collected and analysed.

The method used for this study is not described in other literature and constitutes a methodologcal contribution. The method could be modified to explore other interactive phenomena and contexts. This would simultaneously allow a comparative evalaution of the method.

The results from Part II will be integrated in the following Part III which addresses research questions 1-5.

PART III
MIMICKING REALITY: TIMING, SQUASH AND STRETCH

Actor Scott Wilson to animator Richard Williams after an animation class:
Of course you realise, Dick, that this whole thing has been about acting
Williams, 2001

15 INTRODUCTION PART III

This part of the dissertation describe interaction design and animation as overlapping areas in a theoretical perspective. The aim is to answer research questions 1-5 (section 7). Answering these research questions represents a contribution to the establishment of functional animation as an independent area of research and practice. The research questions will be addressed by a critical analysis of existing literature. The results from the study presented and analysed in Part II will be integrated.

Research question 1: *How does functional animation position itself in relation to other uses of animation?* will be addressed in section 16 via an analysis of animation studies. Animation studies is the academic discipline that research animation from a scientific perspective. studies represents the state of the art understanding of animation as a research object. The account will show how functional animation positions itself in relation to other research areas within animation studies. The section will present a new model for how to map the relations among these areas.

Research question 2: *Does the interactive context require a different understanding of animation?* will be addressed in section 17 via an analysis of existing definitions of animation. The definitions of animation represent essential understandings of animation by academic scholars and animation practitioners. The definitions provide condensed attempts at answering the question: What is animation? Each definition represent different aspects of animation. Studying a select set of definitions enable an informed and broad understanding of what animation is. Definitions of animation are relevant for this project as definitions must also cover usages witin interactive digital systems. The section establish a definition of animation that covers the overlaps between animation and interaction design. This definition relates to the model for animation studies presented in section 16.

Research question 3: *What are the rationales for including animation and movement in interaction design?* will be addressed in section 18 via an account of animation history: How and why animation over time has developed into its current forms and outreach. The circumstances could be technological, societal, artistic, philosophical, religious, etc.. Inquiery into animation history makes it possbile to identify common areas in development of animation and interaction design. This inquiery present relations to interaction design that have not previously been part of the documented history of animation.

Research question 4: *What are the design principles for functional animation?* will be addressed in section 19 via an analysis of the design principles presented by research and practice in the publications included in the literature study. The existing principles will be unified into a single set of principles that will support practice and allow researchers a single and common place of reference for new contributions and critique. This section will also include an account of the principles of animation that illustrates how these principles applies to practical interaction design.

Research question 5: *How could design principles manifest a framework for design, documentation and communication of movement in the design and development process?* will be addressed in section 20 by the proposal of a model that builds on the principles of functional animation established in section 19 and the notions of motile patterns and motion gestalts suggested in section 13.

These five sections will provide a foundation for understanding how concept of *functional animation* build on and supplement established understandings of animation and integrates with interaction design and thus also how the concept represent both a contribution to the disciplines of animation and interaction design and an independent area of research and practice.

16 ANIMATION STUDIES

Indeed, it is of critical importance to re-explore animation through the intentions of its creator and the contexts in which it is made

Wells, and Hardstaff, 2008

This section address research question 1: *How does functional animation position itself in relation to other uses of animation?*

Animation is commonly viewed as a technique for creating movement in an otherwise static object. Animation is also viewed as an artistic and communicative phenomenon – a type of expression, that allow practitioners of animation techniques to create a product that express something through movement (Wells, 2002). In this view animation is both process and product. As a designer of interactive digital systems I agree to these perspectives, but have proposed a different terminology where animation is the craft and movement the product (section 5). In both views movement is the material. But as interaction designer I also view the product (movement) as a design component that integrates with other components to form the wholeness of an interactive digital systems. This usage of animation is referred to as functional animation and represents a different approach to animation than that expressed by Wells. The following anecdote illustrates this difference: In 2012 I presented the idea of functional animation at the annual meeting of The Danish Animation Society[25] and had an informal talk with keynote speaker Andreas Deja who animated evil lion *Scar* in Disneys *The Lion King*. To my surprise, he described the ability of animation to review the past, understand the present, and describe the future (Baecker & Small, 1990), as “new to him”. It was interesting to hear an

[25] www.anis.nu

experienced and respected animator relate to this understanding as a novelty as I find animations relationship to time quite central in understanding animation. Andreas Deja represents the classic storyteller who creates characters and stories by the manipulation of motion and I represents the designer, who creates interactive environments by manipulating information. Motion being one component in this manipulation. The anecdote illustrates how two different contexts making use of animation have different understandings of the same phenomenon. However, these understandings are not incompatible, but the variety of perspectives constistutes a challenge to animation studies.

Animation studies is the study of animation, and as described by Paul Ward, then “Animation is far too diverse to be simply categorized as one single entity” (Ward, 2006, p.243). in a 2003 text on the subject of disciplinarity and discursivity in animation studies he states the challenge for animation studies: “The fundamental problem seems to be: how can we locate or pin down something (and thereby understand what it does, who does it and so on) when it appears to exist in a large number of different places, all at the same time?” (Ward, 2003, p.6). The backdrop for the question is the presence of animated products and thus the relevance of animation studies across a variety of practice and study areas: History, English, Film, Media and Art & Design. Interaction Design joins the line up. The question is whether to view and establish animation studies as a field co-ordinated to these fields, or whether animation studies is an activity taking place within each of these fields. A discussion that is framed by an overall understanding of what Ward describes as the “meeting of disciplines as inter-, cross-, trans,-, etc.” (Ward, 2003, p.2).

Digital technology and adaptation hereof by animators and animation studios has leveraged digital technologies as the primary approach for creating, distributing and viewing animation-products. This development in animation is the focus of Wells, and Hardstaff (2009) who, as contribution to animation studies, set out to explore and describe the re-newed role of animation in the digital media-realm. They talk about “the democratization of animation in terms of contexts of production, application and re-production” (Wells & Hardstaff, 2009, p.20). In the Introduction they write:

> “One of the chief consequences of these developments (in digital image technology, ML) is the elevation of animation as a core term of description for many aspects of creative image-making endeavors . . . Indeed, it is of critical importance to re-explore animation through the intentions of its creator and the contexts in which it is made” (Wells & Hardstaff, 2008, p.6/7).

Wells, and Hardstaff point out that animation has become a cover-all type of expression in contexts that use digital technology for creative image-making, and they ask for an exploration of these contexts and the reasons for applying animation. They do mention computer systems, mobile devices and even have “interactivity” as a keyword in one brief section, but have no structured attempts at addressing the contexts constituted by interactive digital systems as much more than platforms for accessing animated products. Like Ward, then the overall agenda of Wells, and Hardstaff is never the less an argument, and a request for why it is worthwhile and necessary to pursue and research the idea of functional animation:

> "Inevitably, then, ideas about what animation is or might be have changed and it is only through exploring the nature of technology and technique that it is possible to identify, not merely the meaning and effect in any one work, but the particularity of its application in the definition of the form" (Wells & Hardstaff, 2008, p.26).

This agenda of pursueing the particularity of animations application is in line with the hypothesis established (section 4) for researching functional animation as a particular form of animation. Interactive digital systems and the use of animation in this context represents a particular context and definition of the animated form.

Animation has become a highly digital craft and phenomenon and moving into the realm of digital has broadened the scope of application and thus the fundamental challenge to animation studies stated by Ward (2003). Among these new areas are interactive digital systems. As representatives of animation studies, Wells, and Hardstaff provide an account of this "digital turn" and answer many questions and set a relevant agenda, but leaving out the interactive dimension makes their effort not complete. The aim of establishing functional animation therefore represents a useful contribution to animation studies because it represents an interactive understanding of digital media and like animation as a craft, it represents a constructive perspective.

The approach and perspectives of Wells, and Hardstaff (2008) are rooted in a tendency within animation studies to have an artistic and analytic view on animation practice, practitioners, the products and the contexts of application (Furniss 2007), (Wells 1998, 2002), (Ward 2003, 2006) (Israel, 2007). Animation studies tend to see the animated product as a text, the producers as auteurs and analyse them as such.

The research question concerns an account how functional animation position itself in relation to other uses of animation. An account of the field of animation studies is therefore required as animation studies should be the discipline that provide an overview of types and usages of animation. But as described, then animation studies is challenged in this endeavour. To position functional animation it is therefore necessary to establish an understanding of animation studies that unlock and extend the current position.

Like animation studies, then interaction design is usually described as an interdisciplinary field, but has over the years managed to establish itself as an independent field. Possibly because the area of application – designing interactive digital systems - is shared among practitioners independently of their scholarly origin. Interactive digital systems constitute a context with a complexity that necessitates a discipline like Interaction design. Interaction design, is originally integrated competencies from a multitude of fields, all of them collected around the design and use of interactive digital technologies. John M. Carrol describe it this way: “However, the continuing synthesis of disparate conceptions and approaches to science and practice in HCI has produced a dramatic example of how different epistemologies and paradigms can be reconciled and integrated in a vibrant and productive intellectual project” (Carroll, n.d.). It is the context of application: Interactive digital systems, that has shaped this interdsciplinarity into a discipline in its own right. Because of this composite origin, then maybe Interaction design does not have any disciplinary scrouples about including practises and pulling knowledge from neighboring fields. Integrating animation and motion has happened quite effortlessly. This history will be addressed in section 18. Animation on the other hand has had difficulties detaching itself from film-studies. But maybe the digitalization of production, distribution and consumption will provide a basis for animation studies to establish itself in relation to the growing areas of practise. Ward (2003) suggest the following approach:

> “Where exactly does Animation Studies "fit in" with these other areas? My suggestion is that we need to develop a discursive view of apparently "multi-sited" fields of knowledge, like Animation Studies: rather than making what are ultimately false calls for recognition of yet another free-standing discipline, the dialogic and dialectical relationship between fields of knowledge must be seen as the central focus” (Ward, 2003, p.1).

Ward (2003) is not in favour of positioning animation studies co-ordinated to other fields, but aim at defining animation studies as a interdisciplinary endeavour. Julie Klein (2000) list five characteristics of interdisciplinarity identified by William Bechtel[26]:

1. Developing conceptual links using a perspective in one discipline to modify a perspective in another discipline
2. Recognizing a new level of organization with its own processes in order to solve unsolved problems in existing fields
3. Using research techniques developed in one discipline to elaborate a theoretical model in another
4. Modifying and extending a theoretical framework from one domain to apply in another
5. Developing a new theoretical framework that may reconceptualize research in separate domains as it attempts to integrate them

This description of interdisciplinarity is about lifting understandings and processes from one field to another. The fundamental scientific aim for animation studies should be to understand animation (in the boadest possible sense) and to document and disseminate this understanding. In this perspective then interdisicplinarity as described by Klein (2000) provides an attractive epistemological framework, but

[26] Betchel, William (1986). The Nature of Scientific Integration. In Betchel, W., (Ed.) Integrating Scientific Disciplines, Dordrect, Netherlands: Martinus Nijhoof. p. 3-52.

animation studies is also a discipline in its own right. Ward (2003) uses a faultline metaphor borrowed from Klein (2000) and illustrate the relationship between fields that practice animation via Figure 26.

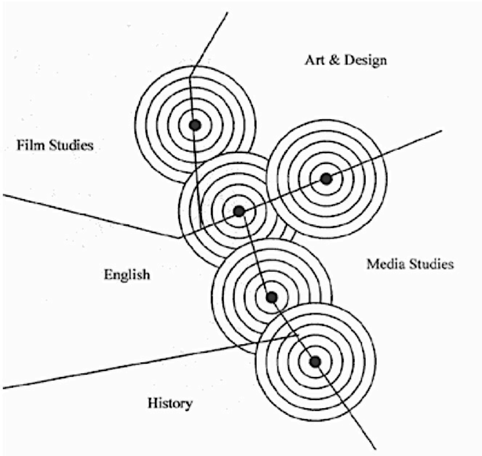


Figure 26. The fault line model of animations relation to disciplines proposed by Ward (2003), Based on metaphor by Klein (2000).

Paul Wards faultline model show how animation practice have epicentres (the dots) at the intersecting lines of various fields. Positioned like this because it by one aspect is an craft and by another aspect provides its expressive services to present content of the neighboring fields. The intersecting lines and epicentres of animation acitivity (= application within this field) turn the lines into faultlines that open up and allow knowledge and pratise of animation to move within and across disciplinary borders, and thus have effect on one another – in the interdisciplinary manner. The metaphor and illustration work well, but animation as not only related to specific fields of practise, it is also as a phenomenon without disciplinary attachment. This is the challenge addressed by Ward (2006) and Wells, and Hardstaff (2008). Ward concludes his thoughts on practise-theory relations in animation studies by saying that:

> A critical reflection on what animation is and what it might be – its conditions of practice and the many different contexts in which it operates – therefore requires that we understand how specific knowledges are positioned by and in relation to other discourses, and how these discourses are in turn positioned by animation. (Ward, 2006, p.244).

This view seperates animation from the discourses (fields) in which it is involved. Ward (2006) fail to mention how the discourses affect animation. Both perspectives are important; in particular if the aim is a "critical reflection on what animation is and what it might be". This point to at least three objectives for animation studies: the practice of animation, the products of animation and theories of animation which captures animation as an interdisciplinary phenomenon - the animated form. But does so as an independent field. Studies of the practises and products inform the theories as also stated by Ward above: "… its conditions of practice and the many different contexts in which it operates".

Interaction design is an interdisciplinary field and context is central to both practice and theory. The challenge for animation studies in positioning itself could be addressed by viewing context as the starting point for understanding and studying animation. To some extend this is done by both Ward (2003, 2006) and Wells, and Hardstaff (2008) as examplified by the previous quotes: "… the many different contexts in which it operates" (Ward, 2006) and "… the contexts in which it is made" Wells, and Hardstaff (2008). Unfortunately their perspective is hampered by a focus on the animated form as a text to be analysed. By focusing on the context of use then animation studies would handle both the specific (the contextual usages) and from this pull common understandings and thus enable exchange among fields that use animation or accumulate these understandings in the theoreis of animation. Animation studies would be a field in its own right. Julie Klein (2000) describe a field in the following way:

> In a landmark study, Darden and Maull (1977)[27] examined how theories bridge two fields. They depicted science as a network of relations, not a hierarchical succession of reductions. The term 'field' designates a central problem, domain of related items, general explanatory factors and goals, techniques and methods, and related concepts, laws, and theories. 'Interfield theory' designates relations between entities or phenomena in different fields and their explanatory role. (Klein, 2000, p. 6).

As by this description, then theories of animation would become "interfield theories" and animation would be an "interfield field" which by 2016 translates into a cross-disciplinary field. Animation studies could make vertical "slices" into different fields (contexts) and then research the contexts of use established by these fields. An alternative illustration of animation studies would therefore look like Figure 27. This illustration has adopted the fields used by the faultline model (Ward, 2003) as example of contexts.

[27] Darden, Lindley & Maull, Nanacy (1977). *Interfield Theories*. Philosophy of Science, Vil.44, No.1 (March 1977), p. 43-64.

Animation Studies: A Cross-disciplinary field						
Animation within x fields (contexts)						
Film studies	English studies	History studies	Design studies	Art studies	Media studies	Other studies

Figure 27. Model for Animation studies based on the fields listed by Paul Ward (2003).

Animation studies is positioned as a cross disciplinary field that covers the contexts of animation usage. The illustration offers an important change in perspective compared to the faultline model which scattered animation studies along the disciplinary (fault-)lines. This illustration acknowledges the contextual usages of animation, but clearly positions animation studies as a field that stands outside these contexts and has a particular interest in the usage of animation, not the field represented by the context. Maybe the reciprocal relation between the animated form and this field, but the study object is animation. The study described in Part II examplifies such an ontological interest as it provides knowledge about both the context represented by interaction design and the usage of the animated form in this context. The latter informs both interaction design and animation studies. It also helps establish a particular usage of animation and thus extends the scope of animation studies and the ability for animation studies to apply these insights in other contexts and in relation to the overall objective of animation theory.

Wells, and Hardstaff (2008) describe how the proliferation of digital platforms has enabled creative activites within various fields to grow and thus also the integration of animation. An example could be the danish television news[28] that have rearranged the studio to have a large open space where static and animated objects overlay the live image. Objects will grow from the floor and spin or trransform while the presenter point to these objects while speaking. It is a novel use of animation and in a context not so easily available to the animated form prior to digital technolgy. In this example the presenter “interacts” with the animated objects via speak, but has no control or influence on the objects that are best compared to an advanced “power-poit-slide”. But within interactive digital systems the interaction is controlled by the user, who will manipulate the digital objects via a proxy like mouse, gamecontroller, etc. or via bodily gestures on a touchscreen or in 3D space. Examples could be user interfaces for production or entertainment systems, simulators for experiencing and learning complex technologies and environments or games where motile objects must respond to both users manipulations and events in the environment. The interactive dimension attributes control of the motile objects to the user and system events. Bill Tomlinson (Tomlinson, 2005) adress this autonomy of the animated

[28] www.dr.dk – accessed September 2016

form from the standpoint of creating characters for games. He propose the terms *linear animation* for those types of animated products where the animator has had full control of the sequence of events and the behaviour of characters, objects and environments. *Interactive animation* is the term for animated products where the animator has no, or very little control over the sequence of events and thus the behaviour of characters and objects. Unpredictable situations may occur and the animated form must therefore have autonomy within the interactive setting to allow negotiation of such situations. This autonomy by non-linear, non-predictable, un-controlled (by creator) characters described by Tomlinson (2005) applies to animation within all interactive systems. One could then discuss the level of autonomy, but the lack of linearity is a common denominator.

Digital technology has not only enabled use of animation in new contexts, but the interactive aspect and hyper-text abilities require acknowledgement of interactive animation as a type of animation parallel to linear animation. Consequently, then the model of animation studies mut be extended with this aspect as the differences between linear and interactive animation is a consequence of fundamental different contexts and purposes of usage. The updated model could look like Figure 28. This updated model is by no means final, but it is proposed to the animation studies community for further discussion as it should address some of the central challenges within animation studies. The model divides animation into types and purposes: Linear and Interactive types as described above, and purposes that describe the goal of the animated product. The suggested purposes are not final, but examples: not exhaustive and shallow in description. This also means that there are not examples for all possible 112 combinations in the current instantiation of the model. Figure 28 is meant to examplify the possibilities of establishing animation studies by this approach.

ANIMATION								
	TYPE:	**LINEAR**				**INTERACTIVE**		
	PURPOSE:	**NARRATIVE**	**COMMUNICATIVE**	**EXPLORATIVE**	**DATA**	**USER INTERFACES**	**GAMING**	**SIMULATION**
FIELD	**DICIPLINE**							
FILM	Feature	Genres						
	Short	Genres						
	Sfx							
ENGLISH	…							
HISTORY	…							
DESIGN	Interaction design			Sketching		**Functional animation**		
	Architecture							
ART	…							
ENTERTAINMENT	…							
EDUCATION	…		RSA Animate		Viz.			Flight
MEDIA	TV News		dr.dk					
	Online News							
MARKETING	…							
SCIENCE	Medico							
	Physics							

Figure 28. The TPFD model of animation studies that allow precise location of functional animation in relation to other animation types and purposes, and context of field and discipline. Three dots "…" indicate that no discipline has been identified.

Within the Linear type the purposes *Narrative*, *Communicative*, *Explorative* and *Data* are proposed. *Narrative* is animation that has a story to tell. This category could be duplicated for interactive animation. *Communicative* is animation where the purpose is to inform. *Explorative* is animation where the purpose is to investigate or examplify ideas. *Data* is animation where the purpose is to illustrate and visualize big data. An example could be Hans Roslings TED talks on various global issues[29].

[29] www.ted.com/speakers/hans_rosling (accessed September 2016).

Within the interactive type the purposes *User interfaces*, *Games* and *Simulators* are proposed. *User interfaces* is animation used to support the functional and experiential purposes of user-sytem interaction within interactive digital systems. This dissertation address this particular purpose within the interaction design discipline. *Games* is animation used for motion within (digital) game environments. This area is quite extensive. Simulators is animation used to mimick situations, technologies and/or environments that the users must learn to master in a controlled setup. As mentioned for *Narrative*, then the purpose categories might be duplicated within linear and interactive animation. It could also be discussed whether *user interfaces* does not overlap into *games* and *simulators*. Such discussions are valid and relevant and support the model as it is the model that makes this discission apparent and allow the results to be located in relation to one another and anoverall understanding of animation.

Animation types and purposes describe the vertical slices of the model. The horisontal perspectives represents the contexts of use. The contextual approach is what led to Figure 27 which had the contexts located on the vertical axis. Figure 28 tilts Figure 27, so that contexts are now on the horisontal axis. Figure 28 includes the contexts inherited from the faultline model and supplementary fields are then proposed. The list is not exhaustive or necessarily correct. Contexts have been divided into *Fields* and *Disciplines* as many contexts will contain particular areas that exhibit special characters, but still relate to the overall context. I have chosen the terms *Field* for the overall context and *Discipline* for sub-areas. I shall refrain form describing all fields and disciplines.

The model allow precise determination of specific usages of animation. The vertical slice (Y axis) provide Type and Purpuse of use and the horisontal slices (X axis) provide the Field and Discipline of use. The model could therfore be named the TPFD model. Where the X and Y meet a specific usage of animation is present (or possible). Not all XY combinations have meaningful content, but this inspire contemplation of whether something could be established in this area. The TPFD model thus also has a creative potential. A few examples are provided in Figure 28 and of course the location of functional animation is accentuated. This accentuation also serves to illustrate how functional animation as by the research hypothesis is a particular use of animation and how this use locates itself in relation to other uses. This answers the research question.

The TPFD view of animation studies illustrated by Figure 28 enable an interdisciplinary approach as characterised by Klein (2000), as I propose an answer to the “Where exactly does Animation Studies "fit in" with these other areas?” question asked by Ward (2003). Animation studies is, by reference to Klein (2000) a “science as a network of relations” constituted by “the dialogic and dialectical relationship between fields of knowledge” (Ward, 2003, p.1) which in a collected format – like the propsed - represent a theory of animation. This might also open up for a wider recognition of animation as an independent field of study, and an affiliation of e.g. film studies. The TPFD approach make the versatility and proliferation of animation apparent. In some areas animation will be the dominant component, and it others it will be one component among many equal-ranking components.

However the TPFD approach should not undermine established understandings of animation. The model does not change existing modulations of animation studies, but offer an alternative framing to better handle the diversity. The XY combinations contain particular incarnations of animations. Some are very complex and contain much of animation as it is historically known. The XY-combination *Narrative-Film* covers e.g. all of Disney and Pixars feature and short-film productions, and similar productions. This is therefore an extremely large area. Unfolding this area access all of the known genres of animated film. Genres relate to particular types of content, certain ways of communicating, certain plot types and specific usages of the expressive material (Wells, 2002). Genres can be broad and have well established forms like Horror, Western, Musical, Science Fiction, or they can be narrow exploratory underground genres which, to some extend represents crossovers among established genres. Wells (2002) propose seven genres of animation based on a understanding of the differences of animated products in contrast to typical genre understandings within film studies. This point of departure illustrate how animation studies are linked to its cinematic history, and thus why functional animation is a contribution to broadening the scope of animation as an interdisciplinary field. Wells (2002) proposes the following genres of animation: *Formal, Deconstructive, Political, Abstract, Re-Narration, Paradigmatic,* and *Primal* (Wells, 2002, p.67-71). The description of *abstract* animation is interesting in relation to functional animation: “Animation that constructs itself as an abstract material or concrete proposition or interrogation, explicitly exploring new techniques and approaches to fascilitate non-objective, non-linear works, or works that resist traditional conventions of understanding and interpretation” (Wells, 2002, p.69). This description does to a certain extend capture functional animation, but the interactive nature is not included. Functional animation is abtract by this definition as it interrogates the form, but the intactive nature cannot be contianed consitently within a definition that must also cover linear forms. This however does not challenge the categories established by Wells but only underlines how digtal technology and interactive digital systems require a parallel place in the overview of animation studies. Instead of forcing interactive animation into exising frames like the genre system, then the TPFD-model support such established understandings and add a new one.

The notion of genres is useful for sub-division of content within the TPFD-model. Within functional animation different technological platforms constitute different modalities of interaction, like WIMP, touch, 3D gesture, virtual reality etc. Each of these represent a unique environment for design, offering a set of restrictions and possibilities. Much similar to the restrictions described for a definition of genres by Wells (2002). Functional animation could therefore contain genres like “Touchscreen interaction”, “WIMP Interaction”, “Web interaction”, VR interaction, etc. The genres will contain examples and motion design guidelines specific for these different interactive environments. The contept of functional animation genres overlaps to the concept of motion gestalts and patterns discussed at the end of Part II. The genres will share some commonalities but they will also represent specialised interactive contexts that require specific guidelines for the implementation of movement. The definition of these specific usages and related design guidelines will establish the motion gestalts and patterns.

Generes of functional animation will follow the overall user interface and interaction design paradigms. This makes a lot of sense as motion is a basic design component, and does not in itself constitute or characterise a type of interaction. Motion is only one of many design components used to design interactive digital systems. Eikenes (2011) propose the concept "Kinetic interfaces" by letting the motile dimension characterise interfaces where motion is used for establishing interactivity. But from this perspective, then all interfaces will be kinetic, as motion, in fluctuating extend and quality, is part of all interfaces. The notion og genres within functional animation implies a perspective where motion is only one of several aspects of an interface. When using a motion component in a design, then a combined understanding of motion and the design context is required,. Collections of such understandings could be seen as genres of functional animation . An interface is not in itself kinetic, but motion may be an important component for establishing comprehensible interaction; which thereby begets a kinetic dimension.

For those animators who venture into interaction design, an understanding of functional animation genres will be valuable as each genre establish different motional requirements. The basic understanding of motion will not change, but the genres represents varying requirements for the motion component. The content of other XY combinations may also be sub-divided into genres and from such investigations new disciplines or purposes may manifest themselves.

The term genre is unusual in relation to interaction design, but it illustrates how functional animation and linear narrative animation could be described by similar concepts and hereby underline the relationship within an overall and common understanding of what it means to work with movement as a design component regardless of purpose. It establishes a common language for exchange of theoretical knowledge and practical experience. A language which by the image of Klein (2000) will help understandings spread like the ripples from an earthquake, into neighboring domains.

16.1 Summary

This section answers research question 1 by establishing a model for animation studies that distinguishes between linear and interactive animation and focus on the contexts of usage within different fields of practice. The TPFD-model allow a precise localisation of functional animation in relation to other usages of animation. This describtion of animation studies is in itself a contribution to animation studies and also verifies the research hypothesis that functional animation represents a particular use of animation.

The contextual approach represented by the TPFD-model challenge the existing definitions of animation studies which mostly relate to the artistic and constructive aspects of animation. A TPFD compatible definition of animation is proposed in section 17 when answering research question 2.

17 DEFINITIONS OF ANIMATION

To be, or not to be, aye there's the point
Shakespeare, 1604

This section address research question 2: *Does the interactive context require a different understanding of animation?*

Section 16 addressed the proliferation of animation and proposed a model for containing the diversity of practices within both linear and interactive animation. This inclusion of interactive animation extends the scope of animation studies and it challenge existing definitions of animation which do not integrate interactive animation.

No single definition will capture all of animation. This position is assumed by most scholars within animation studies. Maureen Furniss writes: "Despite these and other attempts, arriving at a precise definition is extremely difficult, if not impossible" (Furniss, 1998, p.5). Ralph Stephenson says: "This brings us to the question of definition and to some difficulties" (Stephenson, 1973, p.14). This challenge could be due to the versatility of animation as indicated by the TPFD-model. So why bother? Definitions are interesting because they condense often complex understandings into the essence of this understanding. Different definitions will emphasize different aspects of the phenomenon and looking at a selection of definitions is therefore useful in order to get a nuanced understanding of the phenomenon. A definition may also represent an agenda or certain ontology of the presenter and should be understood in this perspective. The definition is not the goal in itself, but the process of establishing it, is an epistemological useful endeavour.

The retention of movement is comparable to how musical instruments harness sound, how paint harness colours and shapes, and how physical materials offer plasticity for creating tangible objects. A definition of animation must harness its essence, so when Thomas, and Johnston (1981) define animation as "Colour relationships in sequence" (Thomas & Johnston, p.15), then they only capture a couple of aspects: a dependency on a visual media, and time. Like music, then movements are ephemeral and depend on the practitiones skill set.

A definition of animation should capture the aspects covered by the TPFD-model (Type, Purpose, Field and Discipline), but also the material of animation, the creative and expressive potential and possibly the media by which animated products are distributed and consumed. But also the abstract and artistic aspects as indicated by Thomas, and Johnston (1984).

This section analyse a selection of animation definitions and thereby compile an understanding of aspects that define animation. This analysis will lead to a definition of animation that supports the TPFD–model.

17.1 Edward Small and Eugene Levinson: Metamorphosis

Small, and Levinson (1989) base their definition on Norman McLaren's definition about the "… invisible Interstices that lie between frames" (Sifianos, 1995) which they refer to Stephenson (1973) who says: "an animated film is one that is created frame-by-frame" (Stephenson, 1973, p.15). This is by Small, and Levinson (1989) transformed into defining animation as:

> … the technique of single-frame cinematography (Small & Levinson, 1989, p.70).

Small, and Levinson validate the definition by its origin with practicing animators: "The fact that the "single-frame" definition stems from technical concerns of working animators does, of course, increase confidence in our choise, but it does not priviledge that choise in any strict logical sense" (Small & Levinson, 1989, p.68).

This is a simple definition that focus on the mechanics that enable cinematography production and consumption - both animation and "live-action". It locks animation to cel-based film technology and Maureen Furniss says, that this definition "… provides the reader with only the most basic characteristic of the practice" (Furniss, 1998, p.5).

The aerin of Small, and Levinson is to define animation as a type of film and they end up comparing animation to "the montage". This is based on interesting observations about how "The control afforded by single-frame cinematography has allowed animators much freedom in distorting spatial relationships within the images they create" (Small & Levinson, 1989, p.70). They observe this control manifested in "… the seperation of graphic components onto individual acetate cells …" (Small & Levinson, 1989, p.70). These are observations which might better suit an artistic definition like Norman MacLaren's which focus on precisely this control of the relation between the physical entities. Small, and Levinson also have another observation of how "animated movement of presumably inanimate objects seems to violate physical law, and many animated pieces exhibit metamorphosis, a change of an obejcts apparent form" (Small & Levinson, 1989, p.69). Unfortunately these observations are not integrated into the definition of animation as Small, and Levinson focus on the product as a type of film and not a creative process that exhibit particular possibilities. This process enable the creation of products, that may rightfully be single frame cinematography, but also show metamorphosis, dissolves physical law and defies space an time.

In the words of Wells (1998), then metamorphosis is based on a deconstruction and manipulation of a physical reality known to the spectator. In this lies animations ability to transform, understood as the ability to manipulate and change *form itself* – to *de-form* one could say. The material is, as pointed out by Wells, the laws of motion within physical reality, and animation becomes the animator's ability to utilise (and in some cases disrupt) the spectator's experience of and expectations for patterns of behaviour determined by these physical laws. In this sense, animation it both natural and un-natural at the same time.

The technology for creating, executing and consuming animation does not in itself define animation. Neither does the technology characterise the expressive potential of animation, but the creative potential in control of the elements to display metamorphosis and disrespect for the laws of physics does set animation apart from other types of film.

17.2 Ralph Stephenson: Creative control

Stephenson (1973) is one of the two sources quoted by Small, and Levinson (1989) as inspiration for their definition. Stephenson (1973) does define the animated *film* as created frame by frame. But he also states: "The cameara is now universally used in making every animated film … and while photography is an invariable part of the process of animation, it is not (as with live action) its very heart and essence …" (Stephenson, 1973, p.9). The interpretation of Stevenson by Small, and Levinson into "single frame cinematography" miss the point. The film is the product of animation, but the frames constituting the film are only "part of the process". Unfortunately the animated film is often referred to as animation, which might be the source of Small, and Levinson's pursuit of "the frame". What defines animation is in Stephensons view explained by the following two statement by which he also explains why he defines *an animated film* as created frame-by-frame:

> The animator is not working as is the live-action film-maker with "bits of reality" (Stephenson, 1973, p.9).
>
> In animation the film-maker has almost absolute control over his material. In the live-action film there is selection and arrangement, otherwise it would not be an art. But in the animated film the artist is more completely freed from the world of reality, limited only by the medium in which he draws, paints, or models, by the structure of the work itself, and by his own imagination (Stephenson, 1973, p.16-17).

Stephenson's understanding of frame-by-frame thus focus on the artistic freedom and control allowed to the animator. This definition focus on the artistic potential. Several observations are similar to those of Small, and Levinson (1989): Control of material and a casual relation to reality. The animators imagination and skills of animation techniques provide creative control over every detail in the construction of the animated product and thus enable the negotiations of time, space and matter leading to the metamorphosis mentioned by Small, and Levinson (1989).

Stephenson draws out the potential within animation as the ability to control every aspect of the creative process towards the mimicry of motion. He does not explicitly refer to movement, but this is implicit by his preceding accounts of animation history. His definition does not address enabling technology as anything else than the frame-by-frame necessity shared with live action film. He mention the medium of creation as restrictive. By medium he refers to the means of expression manipulated by the animator. Structure of the work is also mentioned as a restriction. This is not explained further, but must be the narrative, or other purpose (information, exploration, etc.).

As illustrated by the TPFD-model, then the ability of animation to control the transformation of form has found usage in many contexts. This advancement is driven by digital technology (Wells & Hardstaff, 2008) and the possibilities hereof were recognised in 1973 by Stephenson who wrote: “It is significant that now after seventy years of development animation is turning to computers and other mechanical aids that may eventually ease the burden of its hand methods” (Stephenson, 1973, p.9). Small, and Levinson provided their defininition in 1989, 16 years after Stephenson (who is also their source), but did not consider the influx of digital technology on how to define animation. 1989 is the year the animated .gif specification was released[30]. Of the two, Stephenson’s definition is the most promising as it does not relate to a particular technology, but focus on the creative freedom in creating animated products.

17.3 Norman McLaren: Expressivity through movement

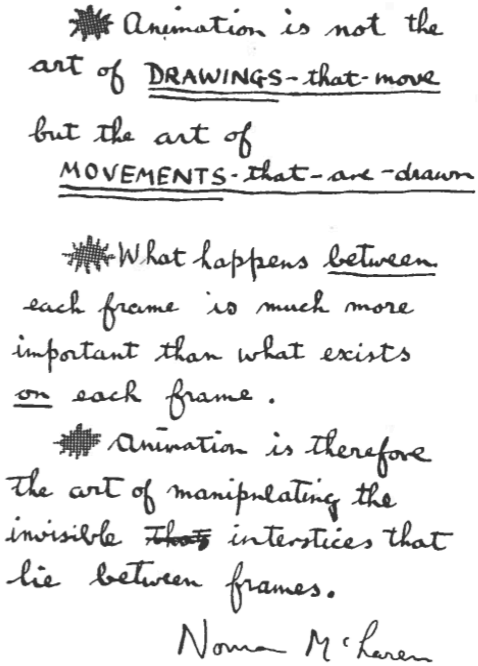
Norman McLaren was a scottich born pioneering animator who experimented much with the animated form (Stephenson, 1973). McLarens definition of animation is probably the most referenced of all definitions:

> 1. Animation is not the art of drawings that move, but the art of movements that are drawn.
>
> 2. What happens between each frame is much more important than what exists on each frame.
>
> 3. Animation is therefore the art of manipulating the invisible interstices that lie between frames (Sifianos, 1995, p.62).

McLaren’s definition points out the space of opportunity that exists between each frame. The rhetorical question being: How does state A transform to state B, what happens between A and B? This is the artistic space of animation where the expressivity of the movement is created. The defininition is, by my interpretation, in line with Ralph Stephensons definition as the form on and of each frame is the a

[30] www.w3.org/Graphics/GIF/spec-gif89a.txt - accessed September 2016

result of the animator exercising imagination and control of the material. McLaren never publicised the definition himself. Small, and Levinson refer to it as a scrawled note, attached to some equipment, being noticed by a visitor to McLarens studio.


Animation is not the
art of DRAWINGS-that-move
but the art of
MOVEMENTS-that-are-drawn

What happens between
each frame is much more
important than what exists
on each frame.
Animation is therefore
the art of manipulating the
invisible ~~that~~ interstices that
lie between frames.
Norman McLaren

Figure 29. Norman McLarens definition of animation as reproduced in Sifianos (1995, p.62).

Georges Sifianos traces McLaren's definition to publications as far back as 1957 (Sifianos, 1995). But in 1986, when Sifianos was writing his doctoral thesis and tried to "discern the true essence of animation" (Sifianos, 1995, p.62), he wrote McLaren to clarify whether the statement "movements that are drawn" is literal or metaphorical, and also why McLaren specifically focused on "what happens between each frame". Sifinaos (1995) is an uncommented reproduction of the written response to Georges Sifianos by Norman McLaren that modified the otherwise well known definition:

> If I were rewriting the three statements today, I would eliminate the first and second, and I would say something like this:
>
> For the animator, the *difference* between each successive frame is more important than the image on each single frame. It is the heart and soul of animation. The graphism, though very important too, is of secondary importance, Animation therefore is the art of manipulating the *differences* between successive frames, or the image on each frame (and should not be confused with the

> excellence of the graphism itself) (McLaren, 1986, in Sifianos, 1995, p.66).

This second version, McLarens II, is more concrete than in the first version, McLaren I. McLaren II focus on the *difference between frame contents*. Difference is emphasized by explicitly making the quality of graphic appearance secondary. The focus of McLaren II is the expressive possibilities in the difference between the states, the frames, and thus the movement being created. The definition also explicitly focus on the animator as the creative force and emphasize the act of manipulation to create the differences.

McLaren does, like Small, and Levinson (1989), and Stephenson (1973), not mention movement in his definition(s). He does in statement 1 of McLaren I, but this is to move focus from the illusion to the process. A process which in McLaren II is explained by the manipulation of differences between the individual frames. In this perspective, then Stephenson's and McLarens definitions overlap as animation is defined as the animators creative space by control of content within each frame. Animation by this perspective is therefore an artform dependent on the skillset of a craftsman. But the result, when the frames are stitched together and projected in rapid succession is the illusion of movement. This is the goal of the animator: To create movement, not frames.

In his letter to Georges Sifianos, Norman McLaren elaborates his understanding of animation and answers Sifianos questions. McLaren *did* speak metaphorically about "movements that are drawn", as what he meant was: "The critical decision which the animator has to make has to be made between first drawing and the second drawing - just exactly how much *movement* he has to make" (McLaren, 1986, in Sifianos, 1995, p.63). This explanation address the artistic process and then point to the resulting movement. The goal of the decisions on difference is *movement*. As McLaren explains, then the animator has "… to think of it as a continuous series of moves in advance" (McLaren, 1986, in Sifianos, 1995, p.64). This also point to the real material of animation which is not the "graphisms" or models manipulated, but movement:

> The good animator knows the correct amount of differentiation by *instinct*, by observation, by experience. He *feels* it, if moving a cut-out or object, or a series of drawings.
>
> As the Renaissance artist and all other painters in the realist tradition studied the *anatomy* or people, faces, forms and things around him, so the good animator studies the *anatomy* of the *motions* he sees around him (professionally, we call them "calibrations") (McLaren, 1986, in Sifianos, 1995, p.65).

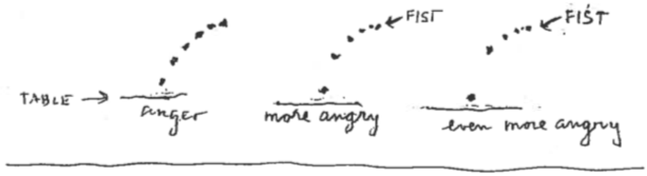
The true skill set of the animator lies in knowledge of movement and being able to use this knowledge to create movement by manipulating the contents of each frame to have the difference that will create the intended expression. The book "The

Animators Survivalkit" by Richard Williams is a richly illustrated introduction to such studies described by McLaren (Williams, 2001).

McLaren list the five basic categories of motion that he has identified (McLaren, 1986, in Sifianos, 1995, p.64):

1. Zero motion: Stationariness.
2. Constant motion: With a full range of tempos, from very slow to very fast.
3. Accelerating motion: Ranging from gradual to steep
4. Decelerating motion: *no explanation (ML)*
5. Erratic motion: Seldom used

These are all aspects of the principle "Timing", which is one of the 12 principles of animation described by Disney animators Thomas, and Johnston (1984).



- Illustration of the acceleration of movement: the arm and fist of an angry man pounding on a table. From McLaren's letter to Georges Sifianos.

Figure 30. McLaren illustration of "timing" in his 1986 correspondance with Georges Sifianos (Sifianos, 1995, p.65).

Timing is one of the most, if not *the* most important principle (section 19.1). MacLaren uses the example of putting down an angry fist, where the location of an object (the fist) within the frame defines the expression of force (Figure 30). Speed, acceleration, decelleration and thus force and expressivity of the motion is created by the time build into this location of the moving object within each frame. McLarens category 1 is "no motion", the object stays in place, but time will still pass. Motion by McLarens definition is object behaviour over time – is it static, does is shift position, does it shift shape.

Animation, by McLarens definition, is expressivity through movement.

This is in line with the understanding of bodily movement presented by Maxine Sheets-Johnstone: "Whatever the variation, the movement has a distinctive felt qualitative character coincident with that variation, a felt physionomic aspect which is in fact a constellation of qualitative aspects" (Sheets-Johnstone, 2011, p.142). She describe these qualitative aspects as: "… four primary qualitative structures of movement having to do with force or effort, with space, and with time" (Sheets-Johnstone, 2011, p.143). A description which is in concordance with McLarens definition. Sheets-Johsntone is a philosopher and a dancer and thus approaches movement from perspectives different to those of McLaren. Sheets-Johsntone has experience on movement from manipulating her own body and McLaren has experience on movement from manipulating various physical materials. Their perspective on movement as an expressive phenomenon are therefore different, but they reach similar conclusions. McLaren highlights timing as essential for movement to have the desired expressivness, which is elaborated by Sheets-Johnstone's four basic qualities:

I. Linear (spatial)
   - The linear design of a moving body
   - The linear patterns created by movement itself
II. Amplitudinal (spatial)
   - The areal design of a moving body
   - The areal patterns created by movement itself
III. Tensional (temporal)
   - The intensity of a movement. The effort, the force.
IV. Projectional (temporal)
   - The character: Sustained, abrupt, explosive, ballistic

Linear and *Amplitudinal* both relate to the spatial character of motion. *Linear* is the path taken by a moving object. The standard example witin animation is a bouncing ball, but let's keep McLarens angry fist. The linear quality is the path taken by the fist, and thus the space travelled by the obejct. Williams (2001) point out how movements rarely follow straight lines. Only mechanical objects follow straight lines. The *amplitudinal* quality is the extend of space covered by the travelling fist. If it was not a fist, but an open hand moving towards the table, then the linear qulity could be the same, but the space required by the open hand is larger, than the fist. Linear and amplitudinal thus describe the space of a movement. *Tensional* and *Projectional* both relate to the temporal quality of motion. *Tensional* is the force of the movement, how energetic the movement is and *Projectional* is the intend of the motion, what it is supposed to communicate. These tensional qualities can be constructed from the five basic categories of motion listed by McLaren. Timing, the time a movement require to perform is by McLarens account where the expressiveness is produced.

The categories of Sheets-Johnstone and McLaren does not take into account how movement affects the object. McLaren position the graphism as secondary and thus he does not include the possible object metamorphosis identified by Small, and Levine (1989). The negotiation of the laws of physics is included in the spatial and tensional qualities. Pedantically, then metamorphosis is a result of manipulating the space occuped by an object. McLaren however, does agree with Stephenson on the control of the content of frames (the graphisms), and thus the animators freedom to create transformations and caricatures. But this is not the essence.

How movement affects the environment or visa versa how the movement is affected by the environment is not addressed by neither McLaren nor Sheets-Johnstone These factors were addressed in an experiential perspective by the study described in Part II (section 9) and results showed that environment and object does affect how movement is experienced. This observation is supported by Sheets-Johnstone who extends her obervations on the phenomenological nature of movement, by swapping the perspective from an analytical and creative perspective to an existential perspective:

> I should call specific attention to the fact that movement creates the qualities that it embodies and that we experience; thus it is erroneous to think that movement simply takes place in space, for example. On the contrary, we formally create space in the process of moving … (Sheets-Johnstone, 2011, p.143)

Thus, the moving object experience, and the qualities it presents, like linear and amplitudinal are the result of this same movement. Observable motile qualites are a result of movement and space is characterised by how movement creates it. If an object remain immobile, then space around it is of no meaning. Movement thus negotiates and creates meaning through the control of time, space and negotiation of surrounding matter. A description that match the Part II exercise wich researched the meaning of motion.

This relationship between space and motion position movement outside the realm of animation as established by McLaren, Stephenson and Small, and Levinson. In the existential view of Sheets-Johnstone, motion is no longer controlled by a creator, but the result of interaction. However Sheets-Johnstons realm is he moving body, not products. Movement within the realm of animation should be understood in relation to the two types of animation. Tomlinson (2005) introduced interactive animation and linear animation as parallel types, not exclusive types and McLarens definition of animation as expressivity through movement also suit the interactive type of animation. But in interactive animation there will be a level of autonomy to how the and when the movements are executed. The “consumption” is not controlled by the animator, but by the user of the interactive system.

Sheets-Johnstones philosophical project is about motion as an existential phenomenon which is not only a result, by also a condition of life. McLaren define how to mimic the phenomenon Sheets-Johnstone describe. Animation makes stuff move and this explains why “bringing to life” is often used to explain the effect of animation.

McLarens definition establish animation as the expressive use of movement, but in his explanation he includes a dependency of the frame-by-frame production modus and reproduction technology. This of course has a historic reason, and is not a precondition for maintaining *movement as the material of animation* and as supported by Sheets-Johnstone’s phenomenological categories, then this material is manipulated via a consecutive establishment of difference within the four spatial and temporal qualities. Irrespectively of the type of animation – linear of interactive.

Figure 31. Frame from Pas de Deux by Norman McLaren, 1968.

I should like to conclude this analysis of Norman McLarens definition with an anecdote that connects his work to a recent work in exploring information technology. Norman McLaren was interested in the ephemeral nature of movement. His work “Pas de Deux” received a BAFTA Award in 1969. In this black & white film the dancers leave traces of their movements, and they abandon poses, while an outline of the pose is maintained static, this abandoned might then, by a little delay, move and pick up the movement already performed by the dancer. The dancer dances with instances of her own poses. This work reminds me of a work from the Oslo School of Architecture (AHO), where a 2 meter beam with LEDs has been filmed while carried through the streets and parks of Oslo. The LED-beam light up when Wifi signals are picked up. The resulting film shows the traces of Wifi as a continuous line of light across the Oslo streets and terrain. Like the dancers of Pas de Deux, then the replay of the moving light beam make visible the invisible.

17.4 Alan Cholodenko: Control of reality

Alan Cholodenko provides a poetic definition which appears a little complicated by first read, but accentuates the constructive element of animation practice.

> It is also the animatic apparatus that draws life and motion forth and at the same time withdraws them, seduces them, drawing/extracting the life and motion from them, turning the animate inanimate as it turns the inanimate animate, a life that is inescapably complicated with death and with the machines of the graph: the life of lifedeath. Articulating the animate upon the inanimate, animation draws drawing, that is, draws death to life and life to death at the same time, as it simultaneously draws motionlessness into motion and motion into motionlessness (Cholodenko, 2000, p.3).

Cholodenko is redundant as he describe the same dynamic three times: “turning the animate inanimate as it turns the inanimate animate”, “draws death to life and life to death” and “draws motionlessness into motion and motion into motionlessness”. By these poetic descriptions Cholodenko draws attention to how the practice of animation is build on the "calibrations" described by McLaren: The observation and deconstruction of movement in "real life" and the subsequent re-construction of movement in the animated product via the parts created by the deconstruction. The abstract pieces of this deconstruction are collected in the 12 animation principles (Thomas & Johnston, 1984) and more detailed guidelines are described by Williams (2001). The animator may then add own experience.

Cholodenko elegantly describes how animation requires an intricate knowledge of movement in order to instill this ability into otherwise immobile objects, or to create mimicry of real life motile objects. His definition underlines how movement is the material of animation and how control of the immobile content in state A and state B is an expression of the animators knowledge of this material.

The animators understanding of and ability to manipulate movement transgress any medium of expression and by Cholodenkos addition also any object. The inanimate is drawn into life via the installment of motile qualites. Any object, copied from reality of pulled from reality can be motile via animation. This ability positions animation as an expressively powerful craft. As already illustrated by the TPFD-model, then digital technology has been an efficient and capable medium for the animated form. Digital technology offers a breakdown into formal components that appears to match the similarly deconstructive foundation of animation. And like animation, then the material of digital tehcnology, information, is as ephemeral as movement.

17.5 Scott McCloud: Information and aesthetic response

This definition originates from Scott McClouds 1993 book "Understanding Comics". By todays standards it might be referred to as a *graphic novel*. But the purpose is not storytelling, but to describe the Comic as art-form. This is done via the means of the media itself. In the book he defines a comic: "Juxtaposed pictoral and other images in deliberate sequence, intended to convey information and/or to produce an aesthetic response in the viewer" (McCloud, 1993, p.9). This is not a definition of animation, but as McCloud writes, then a comic is "images in deliberate sequence" which is very much the same as frame-by-frame. A slight adjustment will therfore create a definition of animation:

> "Juxtaposed pictoral and other images in deliberate AUTOMATED (ML) sequence, intended to convey information and/or to produce an aesthetic response in the viewer" (Lund, 2015 paraphrasing McCloud, 1993, p.9).

The comic and the linear animated film has much in common as the purpose is to progress the communicative effort one image at a time. The first part of McClouds definition is almost similar to Small, and Levinson's "single-frame cinematography" definition. The big difference between the comic format and the animated format is the transformation of content to a moving image format. A contemporary example is the movies based on DC Comics[31] and Marvel[32] characters like Spiderman, Batman and X-men. The films in these universes relies heavily on computer generated animation. Transforming a definition of comics into a definition of animation is therefore obvious. The second part of this converted definition is interesting as it adds a new perspective.

The previous definitions by Small, and Levinson, Stephenson, McLaren and Cholodenko address the expressiveness of animation and the animators skillset, but they leave out the perspective of the audience. They do address the animators expressive intend and thus indirectly the presence of an audience. McCloud explicitly includes this perspective as he describes how the product is "… intended to convey information and/or to produce an aesthetic response in the viewer". This statement even manages to cover two purposes: to convey information or to produce an aesthetic response. These aspects match the TPFD-model where the linear and interactive animation types are broken down into specific purposes (Figure 28). The suggested purposes also cover these two proposed by McCloud.

The study presented in Part II illustrated that the experiential and affective effect of the animated form is dependent on both recipient, context, media (tool) and goal. Acknowledging the communicative purpose and interpretative possiblities is an important aspect of creating a meaningful product. Animation is also communication.

McClouds definition also brings out an obvious trait of animation: Animation is visual and only achievable in materials that have a visual property. It is not possible to animate sound or smell. Stereo and surround sound does support the perception of movement in movies and may also instill the experience of motion without corresponding imagery. But this is not animation. Animated products often incorporate sound and the sound probably enhance the motile experience. But animation is traditionally connected to a visual expressivity, but future digital technologies might challenge this.

17.6 Computer animation: No frames, no limits

In 1995 Buzz Lightyear exclaimed: "To Infinity … and beyond". Buzz is a now famous character (Figure 32) from Pixars 1995 Toy Story film and his bon mot is fitting for the evolution in computer based animation that he and the Toy Story team of characters heralded. The previous definitions all related to the frame-by-frame approach to animation, but digital technology has dominated and affected the entire 21st century image-making industry: "... the computer as not merely the facilitator of processes involved in creating moving image works, but generating moving images too" (Wells & Hardstaff, 2009, p.). Digital animation technology is not dependent

[31] www.dccomics.com - accessed September 2016

[32] Bought by the Walt Disney Company in 2009 -

on the celluloid film format and thus “the frame” is not a defining factor for digital animation.

Figure 32. Buzz Lightyear, Space Ranger and computer animated character, 1995. © Pixar Animation Studios.

In perspective of functional animation, then digital technology, and thus computerbased animation is a precondition for the emergence of this particular use of animation. The developments in and of digital technology has made interactive animation both necessary and possible, and as pointed out by Wells, and Hardstaff, then digital technology has also affected linear animation. The framing provided by digital technology has affected the creative circumstances as well as planning, production, execution, and consumption of animation. The question therefore is: Has digital technology affected the animators creative space and view upon their craft? And consequently: does this affect the established understandings of animation expressd in the previous definitions?

Parent et al. (2013) define computer animation as:

> … any computer-based computation used in producing images intended to create the perception of motion (Parent et al., 2013, p.4).

This definition emphasize the computational circumstances for the creation of motile imagery and then state the purpose of instilling the viewer the experience of motion by this imagery. The definition is somewhat like Small, and Levinson (1989) that also focused on the production apparatus. But Parent et al. (2013) does, like McLaren also create a focus on movement as the result, but are not concerned about the expressivity of this movement. Parent et al. also describe computer animation as “motion control” which is aslo a way of describing how animation relates to motion in general, and not only within computer animation. Parent et al. (2013) move on to describe how computer animation is produced and thus how to understand animation in an environment dominated by digital technology. They propose three approaches:

1) *Artistic animation* provide the animator full control of the animation process, but within the digital realm. This is what Thomas (1998) refer to as *computer aided animation* (section 11.1.2) and in principle a process that supports the appraoces described by previous definitions.

2) *Data-driven animation* is based on the capture of live motion which is then tweaked via graphic and motile manipulation in the computer. This is known as the technique of motion capture.

3) *Procedural animation* is based on digital models which are then manipulated to achieve the intended motion. This is what Thomas (1998) refer to as *computer controlled animation* (section 11.1.2). (Parent et al., 2013, p.4).

These three approaches illustrate a spectrum of control going from full control during the image-making process to only editorial control of the computergenerated imagery. How this spectrum affects the animators creative space probably depend on the context. The artistically oriented animator would probably prefer the *artistic animation* approach and feel constrained by the *procedural* approach. Whereas the animator producing pieces for the danish television news as described in section 16 would appreciate the assistance offered by *procedural* animation. In the 2003 BBC film "From Pencils to Pixels" John Lasseter, Animator, Director and Creative officer at Pixar describes the process of computer animation:

> These films are lovingly handcrafted frame, by frame, by frame. Everything in a Pixar film is there to help tell the story. One of the things you have to remember about animation in general, but especially computer animation: You get Nothing for free. When you look at a Pixar film and the incredible detail in there. Every little piece of detail, whether it's in "Nemo" that the stuff floating in the water, the beams of light coming in. Had to be thought of, had to be designed, had to be modeled, had to be, you know, the software created in order to do it. Had to be placed. Had to be directed. You know, that is why our films take four years to make (Yentob, 2003, 30:00).[33]

John Lasseter is probably not overly critical as he pioneered computer animation for feature length movies. But he does describe the process (at Pixar) by similar elements as those stressed by Small, and Levinson, Stephenson, McLaren, Cholodenko and McCloud. He also mention the interesting aspect of software: " … the software created in order to do it". As explained by Lasseter, then the attention to detail and the knowledge of McLarens calibrations is relevant, but digital technology provides tools to handle and animate particular elements within the environment. In "Finding Nemo" a special software was developed to create the

[33] Transcript by ML. Timestamp: 30:00

look of being under water and for Disneys "Brave" the animation of Princess Merida's hair was handled by a rendering software called Taz[34]. Parent et al. (2013) list the following controllable parameters: Position, orientation, shape, shading parameters, texture coordinates, light source parameters, and camera parameters. But they later add that *any* parameter is open for animation. In pinciple any object quality, with a numeric value, can be manipulated and thus used for motion control. This suppors the aspect of metamorphosis and disregard of the laws of physics mentioned by Small, and Levinson (1989). The rendering and motile control of specific hair-strands illustrate the detailed control and possible breakdown of calibrating entities offered by computer animation.

Not only does computer animation exhibit control over more details than possible by analogue methods, but the software used for Princess Meridas hair could be reused for other characters. The "bits are bits" nature of digital technology (Negroponte, 1995) also applies to the elements used for animation which may be reused and tweaked as necessary. This control over detail and reuse ability is also described by Parent et al.:

> While computer animation has borrowed the production approaches of conventional animation, there are significant differences between how computer animation and conventional animation create an individual frame of the animation. In computer animation, there is usually a strict distinction among creating the models; creating a layout of the models including camera positioning and lighting; specifying the motion of the models, lights, and camera; and the rendering process applied to those models. This allows for reusing models and lighting setups. In conventional animation, all these processes happen simultaneously as each drawing is created, … (Parent et al., 2013, p.19-20).

By this account reuse and preparation of reusable models[35] is a defining trait of computer animation and Parent et al. list several creative steps leading to "the rendring process applied to those models". A model is a character or an object that has to move within the animated scene which is then rendered. Rendering being the process of generating images and motion sequences. Computer animation models are build by socalled "riggers", who design the motional attributes of a model. The model is manipulated by the animators to create motile expressions. The computer animation thus comes to share some properties with puppetry, except for the significant difference of real-time performance in puppetry and "absolute form" in animation (Wells, 2011). Clay animation share the model and reuse properties with computerbased animation, but is based on camera-technology for capture of frames.

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[34] moviepilot.com/posts/3806336 (accessed October 2016).

[35] Rendering of the Princess Merida model: www.youtube.com/watch?v=7IXKCzko2gM (accessed October 2016).

This brief account of computer animation does not indicate that digital technology has affected the animators creative space. The technical circumstances have changed, but from Lasseters description, then the expressive potential of animation has not changed by digital technology. This is also the basic argument in his 1987 account of how to apply the 12 animation principles by Thomas, and Johnston (1984) to computer animation (Lasseter, 1987). Computer animation has created new opportunities for creative control. Some might claim that the digital material limits the expressivness to a certain aesthetic, but the understandings of animation established in the previous definitions have not been affected.

Digital technology has exended the usage of animation and the outlook of animation could be: to infinity … and beyond.

17.7 Maureen Furniss: Mimicry of reality

Maureen Furniss (2008a) provides a definition that describes the relationship between animation and live-action film. The definition is based on a continuum of mimicry reaching from concrete to abstract. A continuum is a scale without any thresholds between stages. A continuum is therefore useful when describing a gradual change.

Concrete		**← mimicry →**			**Abstract**
Sleep	Jurassic Park	Who Framed Roger Rabbit	Bambi	Hen Hop	Kreise
Andy Warhol	Steven Spielberg	Robert Zemeckis	Walt Disney	Norman McLaren	Oscar Fischinger
1963	1993	1988	1942	1942	1933

Figure 33. The continuum definition (Furniss, 2007).

The continuum is illustrated by Figure 33. At the concrete end are films that are not edited, but present reality as it happened when filmed. An example could be the film ”Sleep” (1963) by Andy Warhol which show a man filmed in his sleep. The character is not acting as he is sleeping and thus without any control by own a directors intend. The film only has one subject, but does feature cuts, zooms and changes in viewpoint and perspective. Warhol created the film as an ”anti-film”. A more recent (and succesful) example is the norwegian ”slow-tv” which among other subjects show 7 hours of uncommented film from the front of a travelling train[36]. Slow-tv may be further towards the concrete end of the continuum than ”Sleep” which has editorial elements. At the other end of the continuum is abstract animation. Abstract animation as a genre was defined by Wells (2002) in section 15. In Furniss' (2007) version, then abstract animation are films where form is the only content. These movies have no reference to any known objects of situations. They

[36] www.nrk.no/presse/slow-tv-1.12057032 (accessed October 2016).

are only movement of forms. Furniss (2008a) point to the film ”Kreise” (1933) by Oscar Fischinger which show circles of various colour and size move about. The moving graphisms are accompanied by music[37]. In between these two extremes are four more examples. At the end of absolute mimesis, next to ”Sleep” is ”Jurassic Park” (1993) by Steven Spielberg where the animated dinosaurs are supposed to appear real – to mimic reality and to make the audience believe in these characters. Contemporary exmples are the many adaptations of Marvel and DC Comics superheroes to the living image format. Toward the middle are films like ”Who framed Roger Rabbit” (1988) by Robert Zemeckis which blend live action cinematography with obviously animated characters. Moving further in the abstract direction are classic Disney films like ”Bambi” (1942) by Walt Disney. This type of movie is fully animated, and utilise the animated form to negotiate the reality of the characters, objects and environments and create caricatured, but believeable characters and actions. Bambi skating on the lake is totally un-realistic, but believable due to recognisable movement patterns (Figure 34). The animated form is used for non-realistic behaviour, which relates to metamorphosis and negotiation of physical laws as mentioned by Small, and Levinson (1989). The last example before reaching full abstraction is ”Hen Hop” (1942) by Norman McLaren which show non-naturalistic, but recognisable hens and eggs, that metamorphose and act in peculiar, but motionally coherent ways, in a environment of colour only.

Figure 34. Bambi and Thumber performing in a convincing, but un-natural way. © Disney

The continuum describe a spectrum of moving image products that all reflect a different relation to the reality that they mimick. The very concrete examples are as close to the captured reality as possible. Live action films are located between absolute mimicry, ”Sleep”, and ”Jurassic Park”, an observation not made by Furniss

[37] To have abstract animation accompanied by music is turned around by the software ”Music Animation Machine” which produce animated illustrations from music. www.musanim.com/about_sammam.html I recommend the guitar examples on youtube.com .

(2008a). The continuum then moves through a variety of examples and ends with abstract moving image products where the movements are barely recognisable as referencing any naturally occurring motile patterns. The ”Jurassic Park” type of fims and the ”Bambi” types have a lot in common as animation is an intricate part of making either type believable to the audience. The Jurassic park films use animation to bring fantasy creatures to life along real life actors and environments and the Bambi type films similarly use animation to bring fantasy creatures to life in a fully imagined setting. Only in this latter type of movies the aeshetic is different and movements are allowed to be caricatured. The use of animations negotiation of reality is the same, only the aeshetic is different.

The breakdown of movement allow animators to create movement in objects that do not exist in reality, and to instill movement into objects that do not usaually move by themself, and even to instill movement into objects that are not representations of objects in the real world (Cholodenko, 2000).

The relationship between animation and reality that Cholodenko (2000) and Furniss (2008a) address is put into an existential perspective by phenomenologist Maxine Sheets-Johnstone who views movement as fundamantal to life and to understanding life:

> It is about learning to move ourselves. It is about how movement is at the root of our sense of agency and how it is the generative source of our notion of space and time. It is about how self-movement structures knowledge of the world – how moving is a way of knowing and how thinking in movement is foundational to the lives of animate forms (Sheets-Johnstone, 2011, p.xvii).

Viewing animation in this perspective explain why Shakespears line from Rome & Juliet introduce this section. “To be” is to move and movement is being, or as stated in various incarnations: animation bring objects to life. Animation offers techniques and understandings of how to creatively manipulate the phenomenon that epitomise life: Movement. This relationship to reality is also addressed by Raz Greenberg who concludes: “… that animation is not only a tool that blurs between reality and (re-)presentation[38], as argued in the introduction to this essay, but also a tool that blurs - with unparalleled effectiveness - between reality and its interpretation” (Greenberg, 2011, p.10). This statement describes the continuum established by Furniss (2008a) as the *representation* of reality equals concrete mimicry and *interpretation* is what happens during the movement (sic) towards an abstract mimicry. This also explains the commonality between Bambi and Jurassic Park as they both mimick reality, but Jurassic Park tries to *represent*, wheras Bambi is an *interpretation*.

[38] I believe Raz Greenberg means ”representation”, and not ”presentation” as he states the follwing at the begining of his essay: ”Animation is a leading tool for blurring the distinction between reality and representation, often through its blending onto other forms of media” (Greenberg, 2011, p.3).

However, animation is not magic. Animation is simulation, a replication of the real thing – Bambi, Stomper and the cunning velociraptors do not really exist – except in animated movies. And they do not really move either. The movement is strips of celluloid with juxtaposed static images in a movie projector or rapid parameter calculations and pixel-updates on a computer screen. That list on the touchscreen is not really a list either, but pixels on a capacitative display. This illusion of life, to praphrase the sub-title of Thomas, and Johnston (1984) is dependent on technology and the person viewing the animated product. The technology is a matter of clever engineering and is secondary to how the animated product is experienced. This illusion of life therefore depends on suspension of disbelief by the spectator. The illusion must be convincing.

J.R.R. Tolkien introduce the concept of ”subcreation” (Tolkien, 1964, p.36). Subcreation is a theory on how belief in something fictional arises. Tolkien (1964) places responsability with the author to create a wholeness that by the audience is perceived as consistent and thus believable. In his Lord of the Rings and Hobbit stories Tolkien not only created a narrative with characters, but also worlds, histories, peoples and languages. These elements served to make the narratives believable to the reader. Subcreation is when the reader experience a consistency in the fictional work. Suspension of disbelief is a secondary effect that the reader must apply when the consistency fails.

Greenberg (2011), like Furniss (2008a), view animation as constituted by its ability to relate its audience to reality via manipulations of movement, as also established by previous definitions. The animator must create consistency in the motility of objects as requested by Tolkien (1964) to achieve subcreation. Adding to this potential is the existential perspective of Sheets-Johnstone (2011): that life and the dynamics of reality can be viewed as equalling the movement of and by forms. The ability to manipulate form in real time therefore establish animation as the craft that “brings to life”. Bringing to life could be seen as the essence of animation.

Subcreation happens when the whole presented by the animator make the audience believe, that the characters and behaviours they experience by the animated form, are really performing as perceived. Thereby arise *the illusion of life*.

17.8 Interactive animation: Autonomy and mimicry

Six of the definitions presented in the previous sections all arise from linear animation. The aspects of animation presented by these definitions also appear to apply to interactive animation, but interactive animation may also add aspects to these established understandings.

Tomlinson (2005) emphasize the autonomy of characters in interactive contexts, but Tomlinsons subject is games and he particularly address the autonomy of objects in 3D game environments. Autonomy by Tomlinsons’s account is about the control of the execution of movement in the animated objects. Autonomy could be linked to realism as also done by Furniss (2008a). The autonomy of performing movement in and of the interactive digital objects would exist on a similar axis of mimesis. The scale would have high autonomy at the concrete end and low autonomy at the abstract end (Figure 35).

Interactive animations relation to reality

Concrete/High	← motile autonomy →	Low/Abstract
Simulators	Games	User interfaces

Figure 35. Continuum of autonomy within interactive animation.

At the concrete end are interactive systems with the goal of absolute mimicry of reality. Such systems would provide the user a high level of control over the content and thus also over the motional performances within the system. If illuding life is the essence of animation, then such systems would by this understanding, have motion implemented to mimick the behaviours and reactions of reality upon the users input. Animation and motional autonomy within the system would be an important aspect of the users illusionary interaction with reality – to obtain subcreation. Training simulators and some 3D games would fall into this category. Virtual reality systems are also candidates.

At the abstract end are interactive systems which do not relate to reality. Sush systems would provide the user with low level of control over the content and thus also over the motional performances within the system. The aim of these systems is not mimicry and motion is not implemented to create mimicry. The aim is to support the system functionality. These systems are information systems where the purpose is for the user to manipulate and interact with information. User interfaces are located at the abstract end of the continuum. The autonomy is low because movement performances are fixed to certain interactions and events. The users is subjected to the designers decisions about when, why and which movements to perform.

Defining user interfaces as not relating to reality is disputable and the outmost ends of the continuum will probably never be used. The question is how user interfaces, in the perspective of motion, relate to reality. A continuum for user interfaces may then be established (Figure 36). The mimicry of motion on the continuum for user interfaces is based on how the system reference objects and phenomena outside the system itself.

User interfaces relation to reality

Concrete/Copy	← reference →	Innovative/Abstract
Skeumorphism	Metaphoric	Information

Figure 36. Continuum of user interfaces relation to reality in the persepctive of movement.

At the concrete end are systems which mimic existing incarnations of the functionality via a digital copy. Such systems are skeumorphic. They obtain functionality by enabling interaction and understanding by reference to known solutions. The user will recognise such implementations as something known. The relation to reality is therefore very concrete. The initial incarnations of Apples iOS contained motile skeumorphism like the meter of the Voice Memo App (Figure 37) until iOS 7 introduced flat design. Another example would be the 3D desktop environment BumpTop[39] which gave the desktop metaphor a skeumorphic push by going 100% for a 3D simulation of objects look and behaviour. Movement is an important component in the illusion of maniplable objects achieved by Bumptop.

Figure 37. Skeumorphism in the Apple Voice Memo app before iOS7. © Apple Inc.

At the abstract end are systems which do not mimick existing incarnations of the functionality they present. Such systems could be described as "Information" or "content oriented". These systems obtain functionality by re-interpretating the static and motile form given to the functional and informational presentations in the

[39] Acquired by Google in april 2010. bumptop.github.io (accessed October 2016).

system. These systems do reference reality, but do so in innovative ways. An example would be the 3D gesture based user interface prototyped by John Underkoffler and The MIT Tangible Media Group in 2001[40], and made part of popculture (via computer animation) by Tom Cruise in the film Minority Report. This user interface reinterpretates how the properties of information and thus allow novel interaction. Reality is represented by the usage of functional animation and gestures. Figure 38 illustrate similarities between two examples of abstract renderings for respectively user interfaces and abstrations in Furniss' (2007) film continuum. This comparison point to a common understanding of abstraction as the detachment from reference towards an investigation of meanings of forms.

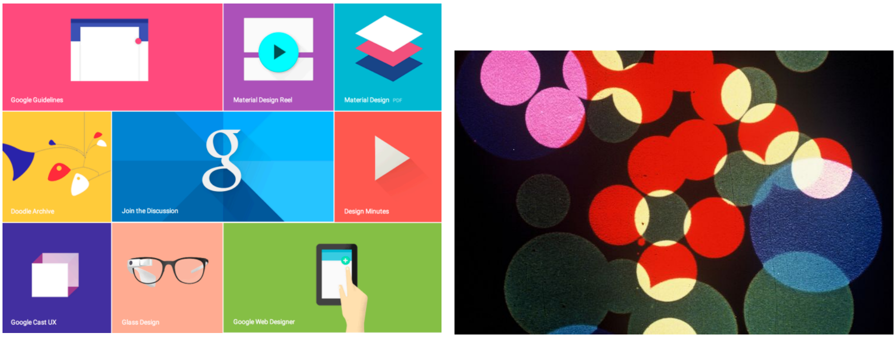

Figure 38. Left: Google Material Design. © Google Inc. . Right: Still image from Oscar Fischinger'sanimated film "Kreise", 1933. © Oscar Fischinger

At the middle of the scale are metaphoric user interfaces which use real world references as semiotic framework for novel designs. The understanding by user is based on reference, but the motile and static form does not aim at actual mimicry, only association.

The Apple iOS "slide to unlock" functionality examplified in Figure 18 illustrates a development in this functional representation from the concrete skeumorphic towards the abstract information-oriented where only shapes and movements represent the functionality. In an example like this it could be speculated whether the motile components are not those, that carry the most reference to reality.

The iPad study presented in Part II explores the relation to reality represented by functional animation. The results on sematic matches confirm the relationship between movement in the user interface and reality. The results showed that users need references to obtain meaningful understandings of the movements they encounter. The skeumorphic interfaces respond to this challenge by absolute reference. The abstract interfaces relies on users prior experience with the functionality and then include relevant components of mimicry. Such components

[40] Now a commercial product. Oblong.com

could be movements which by a consistent installment of ”life” make the interface appear believable. Functional animation make the user interfaces real.

17.9 New definition: Linear and interactive contextuality

Animation as the illusion of life is a grandiose and not immediately applicable definition. A useful definition will include the aspects brought out by the previous definitions and support the understanding of animation purposes and contextuality in usage proposed by the TPFD-model. The following generic definition is therefore proposed:

> *Animation is the control in creation, production, execution, and consumption of motion, as an expressive component, to convey meaning, via a visual media.*

This definition does not relate to a specific technology and is thus independent of frame-by-frame references and linear animation. The definition also covers computer animation and interactive animation where movements are not framebased, but rendered real-time. The definition includes the aspect of control highlighted by Stephenson (1973). The ability to create expressivity through movement by manipulating and negotiate the motile form through difference as hightlighted by McLaren (1986) is included by the word *motion* which is lacking from other definitions. Movement is the material of animation and should be included in a definition. That animation can be understood as both craft, process and product is addressed by the inclusion of the phrase ”*creation, production, execution, and consumption*”. This also include the communicative aspect highlighted by McCloud as *consumption* indicate that someone will receive and try to understand the animated product. Communication is also included by the phrase *convey meaning.* This connects to the *expressive component* part which implies that meaning is encoded into this component. But also that as a component, then movement may and will function expressively in tandem with other components. To convey meaning then movement must reference something known to the recipient and therefore this section of the definition also include the relation to reality exhibited by animation. The last part address the basically visual nature of animation and indicate that some mediating platform is reguired for the designed motion to be realised.

This definition should cover the aspects derived from the definitions of Stephenson (1973) McLaren (1986), Small, and Levinson (1989), McCloud (1993), Cholodenko (2000), Furniss (2008a) and Parent et al. (2013).

The definition is generic and therfore not only a definition of animation. It could also cover puppetry, animatrons, simulacra and eventually robots and other expressive usages of movement. This contrasts the usual definitions of animation, but it is a consequence of digital technology also noted by Wells (2011) in section 17.6. Animation can not be defined by technology as digital technology and also interactive animation dissolves the traditional characteristic. Animation has obtained a broad base of application. Which is basically a good development. The only confinement towards other motile disciplines is the phrase ”*via a visual media*”. However, the definition does state that ”*Animation is ...*” whcich shoudl make it clear that this definition is about animation, and not puppetry. But other disciplines that work with motion as an expressive and meaningful component have always been free to use the detailed understandings of motion established by animation practice and theory. Movement is movement irrespectively of context, but can be controlled differently depending on the medium.

But, the definitions openness allow it to be specific by addressing the purpose and context of use and thus support the TPFD-model. By substituting and adding a few words, then the generic definition becomes a specifc definition:

> *Functional animation is the control in creation, production, execution, and consumption of motion, as an expressive component, to convey meaning, in a visual, interactive, user interface environment.*

The generic definition offers a foundation for defining specific usages of animation – in this case functional animation - that build on and include the rich experience within animation practice and theory. Specific uses of animation may be defined by addressing their particular purpose and context within the ”scaffold” of the generic definition.

17.10 Summary

This section has addressed research question 2: *Does the interactive context require a different understanding of animation?* by establishing a specific definition of functional animation within the frames of a larger understanding of animation. The definition is based on an analysis of several established understandings of animation which makes it possible to position functional animation in relation to other usages of animation and the larger scope of animation practice.

To the established definitions has been added an account of computer animation and interactive animation.

A continuum model for the relationship between respectively interactive animation, and the particular area functional animation, and reality has been proposed by inspiration from Furniss (2008a). The model suggest movement as the factor that makes user interfaces come alive as the overall analysis has shown that the illusion of life is the essence of animation.

Like the TPFD-model, then the generic definition of animation is a proposal for further discussion. The two perspectives support each other as they use context as the foundation.

The important contribution by this definition is not only the modularity, but also the accentuation of movement as the material of animation. Animation controls movement and instills motile qualities into otherwise immobile objects. The result is everything between grandiose feature films and the discrete wobble of a tablet icon.

This concludes section 17. The following section will provide an account of the history of animation and a description of how and why the relationship between animation and interaction design was established.

18 HISTORY OF ANIMATION

Our story, then, begins with the deep-rooted urge of man to simulate the world about him through the graphic and plastic arts. The almost magical, naturalistic rock paintings of prehistoric caves, the ancient grotesque figurines and other 'idols' found in burials, testify to the ancient origin of this urge in primitive religion
D.J. de Solla Price, 1964

The story may not be strictly accurate, but only a pedant would have it otherwise
Bill Tillman, English mountaineer

This section address research question 3: *What are the rationales for including animation and movement in interaction design?*

The history of animation predates the common conception of animation as the playback of 24 drawn frames per second in a cinematic setting. Animation and attempts at mimicking the movement of natural objects can be traced to very ancient times. Because mimicry of motion is also part of the digital tools created in current times to access, communicate and manipulate the world about us, then the historical perspective is an important component in establishing functional animation. Contemporary animation approaches and understandings are a product of the motivations and approaches developed prior to today.

I will provide a chronologic account of animation in three steps. The first step concerns Upper Paleolithic[41] cave paintings. The second step is a brief account of significant events, devices, dates and people within animation history. For more extensive accounts I refer to Williams (2001), Furniss (2008a), and the appendix of Wells (2002). The third step is a thematized account of animation in the user interface of interactive digital systems.

Steps one and three are additions to the established history of animation and are not found in the existing animation literature. These additions are significant to

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[41] The Paleolithic is the era of human technological prehistory from 2,6 million years ago to about 10.000 BC. The periode is divided into Lower, Middle and Upper Paleolithic. The latter extending from 50.000 – 10.000 BC. The first cavepaintings in Western Europe date to the part of Upper Paleolithic known as the Aurignacian (38-29.000 Bc.).

understand mimicry of motion as part of human expressiveness and the subsequent inclusion of motion in human computer interaction design; and thus the establishment of functional animation.

The immediate motivation for the paleolithic step is to correct the widespread misconception in animation litterature and among animators (Thomas & Johnston, 1984), (Williams, 2001) and even archeologist (Herzog, 2010)[42] that our ancestors tried to mimick motion by drawing several pairs of legs on animal depictions. This misconception is refocused onto how motion and liveliness may anyhow be present in these dynamic depictions; and thus indicate the importance of motion as an element of the world worth preserving when making representations of this world. This investigation into paleolithic cave art therefore represent a contribution to the field of animation studies (section 16) and it frames motion as a fundamental attribute for (and in) perceiving environments, objects, subjects, and representations hereof.

The purpose of the historical account of animation in the user interface is to establish when, how, why and by whom animation and movement entered the practice of interaction design. This account produces an overview of the rationales for using movement in interaction design and illustrates the relation between theory and practice of interaction design and theory and practice of animation.

18.1 Proto-animation

As stated in section 2.3 then personal interests and experience might affect the research. I have a personal interest in history and archeology and during my master-studies I spend an internship at the Danish National Museum creating a touchscreen exhibition system about childrens clothing during the past century. This personal motivation represents a negative bias because findings could be based in a need to justify this research perspective; and a positive bias because this contribution would not have appeared without my personal motivation.

[42] Herzog (2010) refers to the documentary ”Cave of Forgotten Dreams” by german film-maker Werner Herzog and is based on his visit to the Chauvet Cave and interviews with the Chauvet research team. This reference therefore consist of not only Herzogs film, but also the statements of individual researchers featured in the film.

Figure 39.The ceiling of bisons in Altamira: Sala de Policromos. Photo from museodealtamira.mcu.es.

The cave paintings[43] of the Upper Paleolithic represents the earliest possible connection to expressions of movement. The Magdalenian people[44] were paleolithic hunter-gatherers in the post-glacial Europe some 15.000 years ago and they are responsible for some of the beautiful and expressive cave-paintings of aurochs, bison, horses, raindeer and other wildlife that are probably best known from the Lascaux cave in France, discovered as late as 1940. The Altamira cave, in northern Spain was discovered in 1868 and the polychrome bison-paintings in the cave are considered among the most exquisite examples of paleolithic cave-paintings found to date (Figure 39). The paintings are composed from up to four different colours using a variety of techniques. Charcoal was used to create figure outlines, which in some cases were smothered to the effect of softening the image contours and

[43] Known a *parietal art*. Meaning paleolithic artistic expressions that are stationary, as in not movable. Contrasted by *mobiliary art* which are artistic expressions created on moveable objects. This category include both engravings and three dimensional models. The finding of Mobiliary artifacts made on/of stone indicate expressive pieces were also created on/of transitory materials like skin, wood, bone, antlers, small rockpieces, etc.. Mobiliary artifacts implies that the parietal pieces were part of a complex of cultural expressiveness and communication.

[44] The Magadalenian periode ranges from 18-10.000 Bc.

airbrushing[45] was used to blow ocre and other colours dissolved in water onto the image body-parts – often in varied intensity, creating an effect of solidity and plasticity in the images. These are all techniques employed by modern day graphic designers and available in digital graphics editors.

The creator apparently also had the depth-dimension in mind when conceiving and executing the work because some of the depictions take advantage of the naturally occurring contours of the rock to underline the curves and forms of the depicted animal. This 3D effect must have been applied in order to make the subject appear more real, more convincing, than a flat 2D surface would otherwise allow.

Figure 40. Panel of the Lions in Chauvet Cave. Photograph by Stephen Alvarez[46].

The natural facets of the rock have also been utilised in the Chauvet cave in southern France, but in some instances the rock is manipulated by incisions around the figure outlines. This enhances the expressive effects and naturalistic occurrence of the painting, which also adds the impression of movement (Herzog, 2010), (Whitley, 2009), (Fritz & Tosello, 2007).

The people of the Upper Paleolithic also produced 3-dimensional mobiliary pieces. For example the renowned "Venus of Villendorf" figurine, which predates the magdalenian by about 10.000 years (Gravettian periode). In the most remote chamber of the Tuc d'Audoubert cave in France, two 60 cm long very naturalistically moulded clay-bisons have been found (Whitley, 2009), (Bahn, 1998).

[45] Paleolithic airbrushing is done by positioning a pipe vertically in a bowl of watery paint and then position another pipe horisontally to blow over the top of the vertical pipe, thereby creating upward suction in the vertical pipe that allow the paint to be blown onto the canvas by the airstream coming from the horisontal pipe. Excavations in Altamira have uncovered hollow feather-stems used to blow paint. Indicating that airbrushing was used for at least some paintings.

[46] Retrieved 30.11.2015 from proof.nationalgeographic.com/2015/01/05/shooting-chauvet-photographing-the-worlds-oldest-cave-art/

These examples of techniques and products indicate an approach to image-making that is far from either crude nor haphazard. Whatever the reason for making these depictions, then they were planned and executed by skilled artist and as a result of careful planning. These are paintings which by todays standard are both technically well executed and possess an expressive appeal.

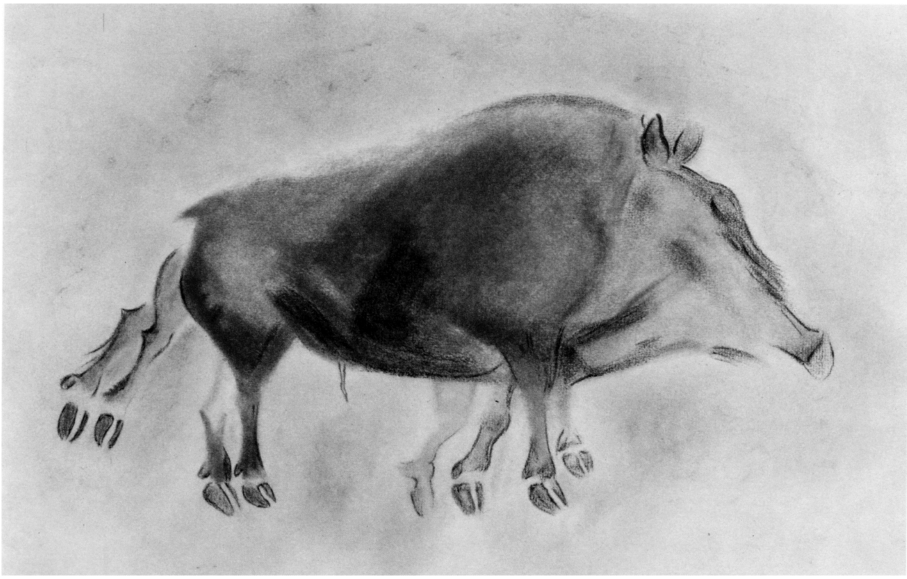

Figure 41.The 8-legged Altamira boar as depicted by Abbé Breuil and Hugo Obermeier in ”The Cave of Altamira at Santillana del Mar”, 1934. Image courtesy of Departamento de Patrimonio/Investigación at the Museo Nacional y Centro de Investigación de Altamira (Appendix E).

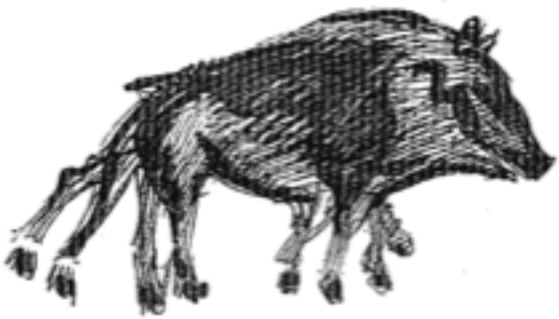

Figure 42. The 8-legged Altamira boar as depicted in Willams (2001).

One of the first illustrations in Richard Williams' "The Animator's Survival Kit" [47] is an 8-legged boar from Altamira (Figure 42). Richard Williams says: "Over 35.000 years ago, we were painting animals on cave walls, sometimes drawing four pairs of legs to show motion" (Williams, 2001) but he does not reference Altamira or any paleolithic scholars about interpretation of the 4 pairs of legs. In the eyes of an animator, then the 8-legged boar certainly does appear as "captured in motion", like two keyframes drawn on top of each other. But the eyes see what the mind is full of, and an animator will be biased to see "proto-animation". However, the Chauvet cave exhibits other examples of apparent movement, that are not immediately dismissable as "proto-animation": An 8-legged bison, a multi-legged raindeer and a rhino with a staccato muliplication of the horn, head and upper body (Figure 43).

Figure 43. Rhinoceros Chauvet Cave. Photo from: www.cavernedupontdarc.fr

Archeologist Dominique Baffier makes the following description of the socalled Panel of the Horses in Chauvet Cave, while gesturing in front of it:

> … their keen knowledge of the animal world, they tell us stories. Here we have an ensemble of horses, but the open mouths of the horses suggest that they're whining. You see that the two rhinos there are fighting. You can see all the signs of fury towards each other. The movement of their legs which are thrown forwards. You can almost hear the sound of their horns colliding against each other

[47] Richard Williams was Director of Animation on the 1988 movie "Who framed Roger Rabbit". His rigorously illustrated book "The Animator's Survival Kit" is a well recognised text-book for learning animation (Williams, 2001).

> in the movement of the fight. … Another story: a female lion growling. She is not happy. She is lifting her lips showing her teeth. Not ready to mate. She sits. The flight of a bison: Almost hear the hooves, Multiple legs indicating its movement. A (multi-legged, ML) bison escaping the alcove following an aurochs (Herzog, 2010, at 41:30).

This is a first-hand example of how the drawings have an artistic expressive dimension that inspires a dynamic interpretation. The description also refer to the multilegged bison as being in motion due to its multiple legs.

One could therefore ask: Would our paleolithic ancestors have made animations, had they had the techniques for reproducing drawings? Maybe, but there is no consistency in the presence of these pieces of potential "proto-animation" and parietal art rarely exhibit any narrative dimension. Depictions of scenes that relate to a progresion of time are almost never seen in paleolithic cave paintings (Leroy-Gourhan, 1982), (Fritz & Tosello, 2007), but some do exist, like the two (apparently) fighting rhinoceros in Chauvet cave and hunting scenes from a few other locations (Herzog, 2010). Furthermore, then the purpose of the drawings must also be considered when looking for traces of movement – would there be a reason for these depictions to stand forth as motile?

I contacted the Departamento de Patrimonio/Investigación at the Museo Nacional y Centro de Investigación de Altamira to get their current interpretation of the 8-legged Altamira boar[48]. The Altamira researchers do not confirm animator Richard Williams interpretation of the boar as proto-animation. Firstly: The depiction can not be confirmed as 8-legged, as it could also be two superimposed images or remnants of the artists corrections. Secondly: The animal is a bison, not a boar which makes sense, since most of the animals in the panel of the "8-legged" specimen are bisons. The presence of multiple legs is doubtful and building a "proto-animation" interpretation on this becomes somewhat dubious. The motile interpretation of multi-legged animals from Chauvet Cave by Dominique Baffiers is alluring, but speculative. In the perspective of animation studies, then this is sad news: Cave-men did not animate.

However, the interpretation of the dynamic and naturalistic nature of the drawings provided by Dominique Baffier is also supported by other informants in (Herzog, 2010) and by (Whitley, 2009). These scholars are all first-hand witnesses and experts on Altamira, Chauvet and many other sites of paleolithic mobiliary and parietal cave-art, and open air rock-engravings. The painting-techniques and thoughts about the three dimensional potentials of the rock contours that went into creating the Altamira, and other pieces of parietal art, indicates an artistic and expressive process and intent that can not be haphazard, but very much controlled and probably very meaningful to both creators and spectators. Archaeologist and paleoanthropologist André Leroy-Gourhan writes:

[48] Response was received in Spanish. This was translated into english (Appendix E).

> The figures that were engraved, sculpted or painted must have signified something, even if they seem to have been produced without any apparent order. Simply looking at several of the parietal assemblages leaves one with the impression that the significance of the groups of figures would clearly emerge in response to the right question. … The assemblies of signs, …, imply an absolutely indisputable intention on the part of those who created them to produce something significant. … the parietal assemblages have the essential characteristics of a message; they respond to the needs and means that man has had since the Upper Paleolithic to produce oral symbols in a material form by using his hands (Leroy-Gourhan 1982, p.43)[49].

André Leroy-Gourhans structuralist endeavour was never acknowledged, but his observations point to consideration of the meaning within both the lines, colours, contours and body positions of each painting and the larger system of meaning among the individual paintings, groups of paintings, their location in the caves, and the people who made and saw them. According to Whitley (2009) then explanations spiritual, ritualistic, entertainment, artistic, competetive and childrens play have been suggested and researched.

Leroy-Gourhan (1982) recognised our paleolithic ancestors as "… fully humanized, cogntively sophisticated human beings, not primitive cave people stumbling haphazardly toward the future, wooden club in hand" (Whitley, 2009, p. 34). André Leroy-Gourhan created a substantial structural analysis of the cave-art. He did not venture into interpretation of the social meaning of the art, but tried to grasp the systemic relationships of the depictions. He broke down the paintings by the following categories (Leroy-Gourhan, 1982):

- Form (Pure geometric, Geometric figurative, Synthetc figurative and Analytical figurative),
- Space (Juxtaposition, Diachronic superimpositions, Addtions and restorations, Partial overlapping, Simultaneous superimposition),
- Framing,
- Symmetry (Mirror symmetry, Symmetry of mass, Oblique symmetry),
- Representation for the ground-surface (Undefined ground-surface, Imaginary ground-surface line, Natural ground-surface line, Ground-surface in linear perspective),
- Animals in unusual positions,
- Perpendiculars,
- Nil animation (Vertical rigid extension, Vertical posed extension)
- Symmetrical animation

[49] This also refer to Leroy-Gourhans structuralist aerin: Uncover and decipher the communicative meaning in patterns (as established by him) among drawings and markings in the caves. This linguistic approach to understanding cave art was never disproven, but neither was it taken up by later reseaerchers.

- Segmentary animation
- Coordinated animation
- Actors: Animals (Grouping/constellations, Individuals)
- Actors: Man and Woman (very detailed breakdown)
- Actors: The signs

The system of Leroy-Gourhan was complex and included parameters related to motile quality and relation of the paintings. The system incorporate the apparent dynamics and liveliness of the paintings, but did not identify traces of cartoon-like assemblages (Leroy-Gourhan, 1982, p. 72). The systematic observations of Leroy-Gourhan does not in themselves generate a conclusion on the "why cave paintings?" question, but they attest the complexity of the imagery found in the paleolothic caves. Among those a presence of motile qualities.

Leroy-Gourhan wrote about the abstract shapes found in the caves: "The geometricism and the frequent graphic complexity of these signs contrasts with the drawing of the animal figures which exhibit the characteristics of an often very close analysis of living form" (Leroy-Gourhan, 1982, p. 55). This observation is supported by Fritz & Tosello (2007) who have backtracked the creation of the images one brush-stroke at a time (Herzog, 2010). This represents a non-interpretative approach to the creative process which show how this approximation to the living form is not haphazard: "The rhinoceros on the right exhibits more complex gestural sequences primarily due to the number of corrections expressed by the artist … The initial rectangular shape of the horn is transformed into a curved appendage approaching anatomical reality" (Fritz & Tosello, 2007, p.64). This realistic intent in the strokes support Leroy-Gourhans notion that the animal figures represent skilled analysis and depiction of the living form. The corrective strokes also reveal an artistic intend toward a naturalistic expression. This realistic intend in the strokes, is supplemented by 3D use of the rock-face and etchings around some paintings.

The apparent naturalistic intent, is supported by Horvath, Farkas, Boncz, Blaho & Kriska (2012) who research depictions of quadruped walking before and after the first photographic pictures of human and animal movement by Eedweard Muybridge in the 1880'ies. The research is based on 1000 artistic depictions of walking quadrupeds spanning the "post-muybridge" area and back through historic time to the Upper Paleolithic. The "pre-muybridge" area presented an error-rate of 83,5% in correct depiction of walking and in the post-muybridge area the number dropped to 57,9%. Muybridges images may have affected the depiction of quadruped motion. However, the Upper Palelithic depictions included in the research presented the lowest error-rate of any sub-group by only 46,2% in-correct depictions. This means that more then 50% of the Upper Paleollithic depictions of quadrupeds had a motionally correct positioning of the legs[50].

[50] Some of the Upper Paleolithic paintings in the study were not european, but of asian and african origin.

This signifies two things: Firstly, it is possible to identify some of the animals as captured in a motile correct stance, and secondly: it underscores the naturalistic intent identified by Leroy-Gourhan (1982) and verifed by Fritz, and Tosello (2007); Whitley (2009) and Herzog (2010). The naturalistic intent is relevant in the animation perspective as it indicate a relation to reality that also defines animation. The people of the Upper Paleolithic did not create proto-animation via eight-legged animals, but they wanted to make the animals depicted appear alive.

Cave paintings were made by people who had the cognitive ability and everyday surplus to evolve a complex culture in which it obviously made perfect sense to venture into the darkest parts of their environment and by both individual and common effort create complex pieces of representation and expressiveness. Shrines with sacrifices have been located in several caves along with preserved footprints of children and adults (The Volp Caves). Remains of scaffolding have been identified (Lascaux) and parts of flutes made of vulturebones have been found at german paleolithic sites. Adding to this is the necessary preparation of colours and painting tools and the effort in transportation and lightning into the darkest parts of the caves. All of this indicate an advanced culture, and a social and religious system that had the surplus and need to prioritise the effort required for creating these paintings in the right locations.

The people of the paleolithic must have had a perception and conception of the world around them that was just as complex as that of their 21st century successors. But without the scientific understandings, complex social systems, technologies and mediations that support contemporary cultures and individuals. The images themselves tell a story about people that wanted (or needed) to express themselves. The artistic and technical skill in these expressions and the choice of postures to reproduce indicates reflection and experience with the creatures that inhabited their common environment. A reflection and experience that include the motile dynamics of these creatures.

The naturalistic and dynamic liveliness of cave paintings is a significant trait not entering western european cultures again for several millenia. To understand this trait, it is necessary to provide an interpretation of the cave paintings that covers both the naturalistic expressivenss and the culture that made the effort to create these works of art. Whitley (2009) present a shamanistic interpretation that explain both the artistery of the paintings, their naturalistic liveliness, and the cultural system that produced them. The shamanistic explanation covers the variations in rock art, both in quality (indicated by the categories of Leroy-Gourhan, (1982)), across sites (caves and open air), across regions in Europe and globally and across the timespan from paleolithic to the near present.

Not all cave paintings have the overwhelming artistic qualities described and not all pieces in the same locations are of the same quality or type. Cave art demonstrates great variability, ranging from pure geometric forms without any likeliness to any living form, to very naturalistic depictions closely resembling the living form and the dynamics hereof. As references to reality, then a continuum of mimicry could probably be established. Leroy-Gourhan (1982) interpretated this artistic variance as a gradual increase in artistic mastery: The millenia made the paleolithic artists better and better. This theory was falsified by the discovery of Chauvet cave in 1994 where the naturalistically very impressive depictions turned out to be 28.000 years old – twice as old as those at Altamira, but equally impressive. The creators skill therfore has nothing to do with the age or the area of the art.

The shamanistic interpretation explain the variation in quality and type by the visions encountered when entering into trance:

> David Lewis-Williams's neuropsychological model for the kinds og imagery experienced during trance, which provided the argument for the shamanistic interpretation, implies that this imagery could vary, even during the course of a single altered state of consciousness experience. The mental images potentially shifted, for example, from simple geometric light images ("entopics"), to construals of the entopics as figurative patterns (i.e., seeing a naturalistic image in a geometric pattern), to full-blown iconic or naturalistic visual hallucinations. (Whitley, 2009, p.115).

In this perspective it is perfectly plausible that the same person could have created images of varied quality and it also explains other traits of the depictions as the absence of any concern with composition is typical of trance-derived images and therfore results in superimposition and no common orientation or respect to a ground-line or horizon (Whitley, 2009, p.128). Even the staccato like depictions and extra pairs of legs can be explaind in this perspective:

> A black rhinoceros was carefully drawn in anatomically correct profile, for example, but it's head was superimposed against a replicated series of larger and smaller heads and horns – the kind of fragmentation and duplication of mental imagery that occurs during trance. A bison was painted with eight legs, perhaps reflecting the sensation of extra appendages that can occur as a bodily hallucination. The curve of the cave wall was used as the back line for an ibex and, in another spot, a horse, as if the animals were really part of the rock surface and the shaman had, as Jean and David[51] argued, "transformed the given into the created". (Whitley, 2009, p. 70-71).

This example is taken from an intepretation of parts of the painted panel in the Chauvet cave where "multilegged animals" occur also described by Dominique Baffier (Figure 40 and Figure 43). The interpretation explain the reason for the depictions as the transformation of the given into the created. The shamans

[51] Jean and David are respectively french archeologist and former Conservator General of Heritage, French Ministry of Culture and former Head of Chauvet Cave Team Jean Clottes and south-african archeologist David Lewis-Williams.

communicated with the cave walls and rendered on these walls what they experienced in their current state of mind, or rather, state of trance. The paintings are manifestations, of what is present *in* the rock. Which explains the use of the rock contours. These are drawings of visions and thus the paintings present what was real. The cave paintings are shamanistic visions present on/in the rock and then made permanently visible to the shaman and the community via these paintings and engravings. As such, then the cave paintings do not interpretate, but represent reality.

Figure 44. Salon of The Bulls, Lascaux cave, France.

Scaffolding was raised to create the Salon of the Bulls in Lascaux (Figure 44). This preparation means that the cration of these images were a community effort. Whitley (2009) does not comment much on how this communal aspect suits the trance-image explanation (Whitley, 2009, p.48). But he acknowledges the communal effort and provides an explanation and first-hand experience of how the appearance of Salon of the Bulls fit an understanding of the paleolithic societies as shamanistic:

> Standing in the middle of the Salons of the Bulls and looking down-chamber, it was impossible not to feel that I was in the midst of a large but strangely silent herd of prehistoric animals that rushed headlong deeper into the cave, carrying me with them into its resesses. And there, in the Axial Gallery where the cave narrows to a

> shoulder's width and begins to plune downward, David (ML: Lewis-Williams) pointed to the paintings of animals that literally swirl up and across the cave roof in a constricting spiral, as if they are spinning into a maelstrom. This, he suggested, was a massive painting of the vortex of the shamans trance, preserved graphically some eighteen thousand years ago, symbolizing that passage into the cave was itself a movement into the supernatural (Whitley, 2009, p. 49-50).

The shaman visions must have been shared with the community and a cooperative effort must have created these images in the passage into the underworld. It must be within this communal effort that ressources for making the complex and naturalistic images have happened. The paintings were basd on the Shamans sketches or directives about what he experienced. The purpose was to bring life to, or make apparent the spirit present in the rock. The pictures had to look alive and movement equals life. Hence the dynamic nature of the depictions.

The paintings along with other findings indicate a cult that made purposeful excursions into the caves where nearness and visibility of the spirits was possible. All of the animalistic cave paintings was created in the dark zone of the caves. None near the entrances. An aspect often emphasized when advocating a cinematic interpretation as the flicker of torches will make the images come alive in the darkness. In shamanistic religions the nature is living and a spiritual world exist in parallel to the physical world. The caves were special places as they provided access to the spririt world. The further into the caves the better the contact to the spirits. The Salon of the Bulls as an image of the shamans "swirl of trance" connects well to the cinematic interpretation. The cinematic effect is present, but not "to show images". The world of spirits was just as real as the physical world and no theatrical effects therefore required. Reality was enough: "They exist not because someone placed them there, but simply because they <u>are</u> there as physical entities in their own right" (Whitley, 2009, p.178).

Shamanism is an appealing interpretation that collects both the paintings and the culture they represent within one explanation. But why it this important for understanding animation and establishing functional animation, whether or not the paleolithic painters were interested in movement? The initial motivation was to verify or falsify the assumption in animation litterature that the people of the paleolithic created animation. That their drawings mimicked movement by depicting animals with multiple legs and staccato-like outlines. This has not been verified. The eight-legged boar of Altamira is most likely two superimposed bison resulting from trance induced visions, and not a conscious artistic attempt at mimicking motion. Paleolithic parietal art is not the beginning of modern animation, but it is, atleast in the words of Whitley (2009) the beginning of human creativity and thus the expressive trajectory that has produced animation as we know it today. Animation and cave paintings share a close relation to reality as either expressive form is based on mimicry and a wish for the spectator to believe the presence and liveliness of the form.

Azéma, and Rivière (2012) believe to have found evidence of thaumatropes (Figure 45) as "proto-cinema" within mobiliary objects. This may be a more valid contender for paleolithic animation than the cave paintings.

In relation to user interfaces then the shamanistic attempt at making the intangible present is allegorical to how user interfaces similarly makes information tangible and manipulable. Cave paintings made the spirits present and created a trangressive medium between the spiritual world and the physical world. An interface, so to speak. User interfaces shape and present an understanding of the ephemeral realm of information. Like the paleolithic shaman, then the interaction designer is responsible for the representations made available to the rest of the community. It is an alluring consequence to name interaction designers the 21st century shamans that establish interaction with the parallel world of information.

The computer animated film "Ice Age" (2002) contains a tribute to cave paintings which also illustrates the essence of animation: The three mammalian heroes venture through a large decorated cave. They come across a panel with human stick-figures chasing a mammoth. The figures mimic the correct style of paleolithic stick-figures and hunting-scenes[52]. The figures then come alive on the rock face as an animated story of the hunt. Thus the animated movie utilises animation to tell a story inside the main story by bringing alive the dynamics of an original paleolithic hunting-scenes. It's an animated movie that animates cave paintings depicting movement.

18.2 Mechanised animation

If the paleolithic did not produce actual proto-animation, then indisputable examples can be found in ancient mesopotamian and greek pottery. A 5200 year old bowl from Iran depicts keyframes of a goat leaping to eat from a tree. The animation manifests itself to the spectator when spinning the bowl while maintaining a steady point of view[53]. Similar examples can be found in greek pottery, but are not common. Storytelling by keyframes is known from many historic artifacts, but none of them appear to have had animation in mind: Ancient egyptian engravings of wrestlers, Trajans pylon in Rome, the Bayex tapestry and others. But none of these are animation. The only thing "moving" is the narrative. Scott McClouds original comic definition cover these pieces (McCloud, 1993).

No references to animation are found between greek pottery and the mid 17th century. No medieval munks created animation to praise the lord, and no animations came out of renaissance Florance. Simulacra and animatrons to simulate movement via mechanical objects did appear, but no mechanisms for playback of the Bayeux tapestry or other narratives.

D.J. de Solla Price provide a historic account of the construction of automata and simulacra (Price, 1964). This account might fill the gap in the history of animation

[52] A very rare event in european parietal art. Lascaux cave contains a single scene.

[53] www.cais-soas.com/News/2008/March2008/04-03.htm (accessed October 2016).

as automata and simulacra are mechanical devices of varying complexity that has the purpose of controlling motion for some purpose. Price's account reaches back to ancient egyptian and greek constructions that in various ways tried to simulate the motile dynamics of worldly phenomena like animals, people and celestical objects[54]. Price explain how these contraptions were constructed to both research and explain these dynamics and thus, as models of theories, have helped shape human understanding and philosophy of the phenomenon in question. He illustrates how the technical savvy in ancient mechanical models were further developed into the advanced clockworks and mechanical tools and wonders created during the middleages (via byzantine influence), through the renaisance (e.g. Leonardo da Vincis mechanical lion), and onwards to the automated instruments and calculating machines of the 17th century (e.g. Blaise Pascals Pascaline) and later, to what Price describes as the "… automation of rational thought …" (Price, 1964, p.23), the Babbage calculators, leading to the "… electronic computer …" using "… memory by the means of the punched tape first used in sixteenth century Augsburg hodometers" (Price, 1964, p.23). The dual focus on mechanical simulation of animal/human motile dynamics and those of celestical phenomena, and thus time, got fused in the clock making traditions of the German Schwarzwald region and in particular the cuckoo clock. The cuckoo clock represents mechanics for harnessing both time and animate life in one device, and thus the similar ambition to simulate, harness and explore human understandings of the dynamics around us, that according to Price, motivated the Egyptians, the Greeks and the scientists of cultures to follow. In this perspective, it therefore seems that animation is not a product of artistic interests, but scientific and technological ambition.

Animation as defined and discussed in section 17 requires a media for consumption, and the history of animation, therefore begins with the first examples of mechanic, sequential reproduction of images, creating, by human perception, the illusion of movement via the differences between images.

[54] E.g. The Antikythera Mechanism found in a 150 BC. greek shipwreck and believed to have the purpose of positioning astronomical bodies in respect to the celestial sphere, with reference to the observer's position on the surface of the earth. It is believed that Archimedes is constructor or contributor for the construction of the device. It is believed that the device is unique.

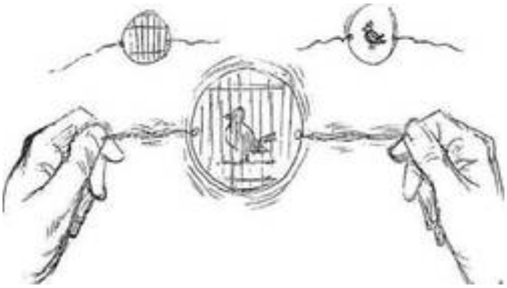

Figure 45. Thaumatrope. Image from Williams (2001).

The mechanical approach to creation and consumption of animation starts with the *thaumatrope*. A thaumatrope is a two-sided flat panel with a string attached to the left and right side. When the string is spun between the thumb and index fingers, then the panel rotates. The rotation of the panel will by the perception of the viewer merge the image on either side, thus creating the illusion of the two images being one image (Figure 45). Images could be a bird and a cage, thus creating the illusion of a caged bird (Williams, 2001, p. 13), or parts of letters which are unreadable without the other part, thus creating a secret message that can only be read when spinning the thaumatrope. The exact time of when the thaumatrope was invented is lost in history. Azéma, and Rivière (2012) would point to the paleolithic as a mobiliary coin-sized artifact with engravings of a doe (respectively lying and standing on either side) has been excavated. But the first commercial thaumatropes were marketed in France in 1825 (Furniss, 2008b). Of course, the two sides of the thaumatrope allow only very little motion to be mimicked, but the general principle of tricking the viewer's perception into seeing something that is not really there – the bird *in* the cage – is the foundation for animation: Creating the illusion of motion by interchanging images in the same visible location. The two sides of the thaumatrope each represent a state – a frame, in an animated sequence. A very short sequence indeed, but adding a few more frames by e.g. a *flipbook*[55], would allow for more complex movement to be illuded.

It could be argued that the thaumatrope does not really produce animation as the illusionary image created by the spinning motion is actually a static image – a bird in a cage, and thus not really a display and reproduction of motion, but rather the use of motion to complete a composite static image. Of course this static image could be referred to as a third image, which by its composite nature is an animated instance of

[55] Flipbook refers to the principle of drawing frames of movement on individual pages of a book or simply a stack of papers, end then by a flipping motion letting the pages display the drawing in sequence and thereby creating the illusion of motion as the pages replace each other. In animation the technique is used by animators to review the connectedness and effect of individual drawings (frames). Flipbooks also appear as stand-alone products and books on animation sometimes have "flipbook drawings" on each page – e.g. Thomas & Johnston (1984) and Furniss (2008b).

the two original images. But still static, though. Furniss (2008a) refer to the thaumatrope as "*two-state animation*" (Furniss, 2008a, p. 124), but also mention more obvious examples of two-state animation, like the mechanics of the *Slip Slide* where two images via e.g. magic lantern projection are interchanged by opening and closing two ports. The basic image position must be aligned and transformations between the two images is then possible: The elephant will get a tiger's head and the lake suddenly shows the Loch Ness monster. Both the thaumatrope and the slip slide allow the image to transform. But the image is static. The transformation is not shown, only the difference between states. But by the definition of Norman McLaren, then this difference is the basis of animation.

The major development of animation happens and accellerates in parallel to the industrialisation and consolidation of modern science in western Europe and USA during the 19th century, and well into the 1960'ies. The development of techniques for producing and projecting animated products, is really the development and history of the moving image and cinema. Cinematography and animation are two parallel developments of technical appraoches to creating moving images. Wells (1998) describes the delopment this way:

> Humankind has always been fascinated by moving images. The desire to make pictures move has provoked some of the most innovative developments in the field of science and technology during the twentieth century. … The driving imperative of the pioneers were largely technological in that they were testing the capability of a new medium in a mechanicistic way rather than artistic way. The development of the camera was more important than the things it photographed (Wells, 1998, p.1).

Wells indicate the same urge as Price (1964, p.10), and underlines that it is an interest in technology and science that motivated the development og both the camera and the subsequent moving image. A develeopment that seems to originate in this urge to simulate motion, and not the aesthetic result itself. A observation also made by Price (1964).

The early mechanisms for mimicking movement in a cinematic format provided motional effect by decimating the spectators area of view within which the different images were then shown via a spinning wheel or other means for sequencing the individual images. Some used drawn images and others used photographs. These were contraptions like the Phenakistoscope (1833), the Zoetrope (1834), the Choreuscope (1866), the Praxinoscope (1877),[56] the Zoopraxiscope (1879), the Kinetoscope (1893) by Thomas Edison and the Phantascope (1894). Magic lanterns of various kinds, combinations and modifications of the above, and eventually the

[56] The 2012 teaser for the annual animation festival in Annecy is a very humourous example of praxinoscopic effect. www.youtube.com/watch?v=jE83TVl4w0c

Cinematograph by the Lumiére brothers (1895)[57] brought the spectales away from the individual and into a social setting as they allowed projection onto a collectively viewable area. This established the components for modern cinema. This is in itself a complex and interesting area of research. Furniss (2008a) and the appendix of Wells (2007) supplement each other with respectively a description of devices and a detailed chronologic overview of significant events in the history of animation. An abridged overview is also found in Table 9.

Paul Wells connects the development of animation as an independent form, to experiments in early trick films at the beginning of the 20th century. These film constitutes, in his words "Magical surprises":

> Trick films invested human beings with extraordinary capabilities, anticipating the animated film's preoccupation with the deconstruction and manipulation of the human body. … In manipulating the image this way, film was able to demonstrate the transgression of physical laws and disrupt the patterns of experience and behaviour determined by them" (Wells 1998, 2009, p. 128).

This description establish the historic foundation for the metamorphosis that has come to define animation (section 17.10). The transgression of physical laws within the trick films creates the metamorphosis that is a defining trait of animation. On-screen elements would become what they could not become, or behave as they would not behave, outside the realm of trick-film. Metamorphosis may not raise eyebrows in year 2015 where animated effects are widespread, but a 100 years ago electricity had recently been discovered and cinemas were only in the wake of becoming part of popular society. Georges Méliès movie "Le Voyage dans la Lune" (A Trip to the Moon) debuted in 1902 and Windsor McCays animated movie "Gertie The Dinosaur" debuted in 1914. Either movie requires the viewer to disregard prior experience of what is possible in the physical world – a rocket that strikes into the live face of the moon, and a dinosaur that actually walks, eats and reacts to objects in its surroundings. The difference between Le Voyage dans la Lune and Gertie The Dinosaur lies in their location on Furniss' (2008a) continuum. Le Voyage dans la Lune is closer to concrete mimicry, than Gertie The Dinosaur. Le Voyage dans la Lune uses manipulation of physical objects and cuts to create the magical surprises. Gertie The Dinosaur is a single piece of "magical surprise" as the whole film is based on different drawings (~10.000) of a creature that does not exist. Gertie The Dinosaur consists of constellations of graphic lines which makes the imagined dinosaur come alive. Gertie is recognised as the earliest example of character animation (Wells, 1998).

Central to the development of animation is the development of photography, as noted by Wells (1998). The camera and capture of individual images led to the film-strip that allowed (almost) endless sequences of images. The individual drawings for

[57] The Lumiére brothers were not the first to invent neither the film camera, nor public projection. But popular history have given them this credit.

Gertie The Dinosaur were photographed to transfer them to the projection format, which then brought Gertie to life via Tolkines "second belief". Reproducing movement therefore goes hand in hand with capturing movement. The inventor of the Zoopraxiscope was Eadweard Muybridge who is known for his photographic sequences of animals and people in motion. He created these by photographing animals and people in various motional situations in rapid sequence (Muybridge, 1887). Most renown is probably his photos of a galloping horse which were commissioned to settle a dispute on whether or not the gallop contains a stage where no hoof is on the ground. Muybridge's photographs for the first time in human history provided indisputable proof that a galloping horse does indeed have a "drifting stage" where no hoof touch the ground. Muybridge captured motion and made it possible to study this otherwise ephemeral phenomenon[58]. He used the Zoopraxiscope to reproduce the motions he had captured. To this day, Muybridge's photos represent the largest single study and documentation of motion. He took over 100.000 photographs and they represent a valuable reference for animators. The Frenchman Etienne-Jules Marey also created photographs of subjects in motion similar and simultaneously to Muybridge. He managed to capture multiple stages of motion in a single photograph (Figure 46). Muybridge did not achieve this.

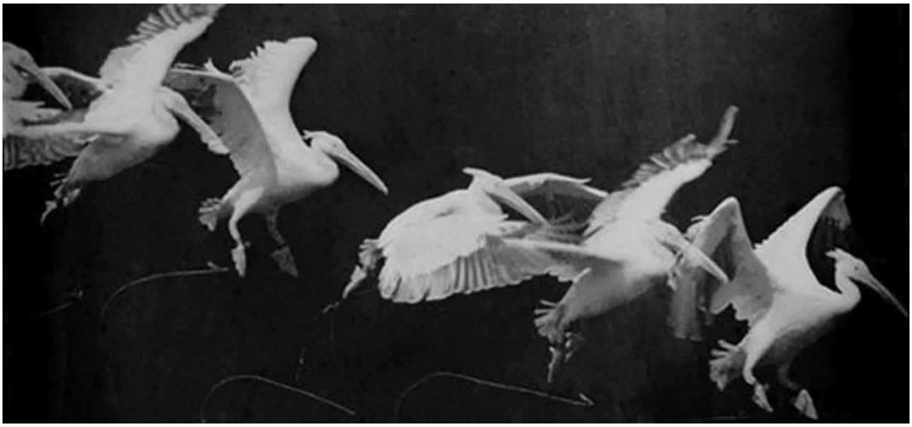

Figure 46. A pelican landing. Etienne-Jules Marey, ca. 1882.

From an animation perspective then Muybridge's photographs are frames. Each frame captures an instance of the physical transformation that a body or object performs when moving. A movement that could be described via Sheets-Johnstone's four basic qualities of bodily movement (section 17.3). Before Muybridge, all reproductions of motion were based on human perception, or single captures with too much time between stages of capture to get an accurate idea of "difference

[58] The Frenchman Etienne-Jules Marey created photographs of subjects in motion similar and simultaneously to Muybridge. He also managed to capture multiple stages of motion in a single photograph. Muybridge did not achieve this.

between stages". As examplifed by the dispute over the gallop, then it was, until Muybridge (and Marey), not possible to study motion. Camera technology made it possible to study a phenomenon hithertho outside the reach of science. The invention of the camara and moving image is in the scientific perspective comparable to the observations of sun spots made possible by the telescope to Galileo Galilei. Technlogical enhancements of human perception.

In Muybridge's photosequences there are lapses between each image. There is a piece of time and space not retained. But the individual images are close enough for viewrs to perceive how a motion is performed and how the living body transforms in the process. Muybridge's contribution was this access to a hitherto inaccessible dimensions of reality: What does motion look like.

Muybridge helped open the pandora's box of manipulating motion through animation techniques. A sequential playback of the individual images mimicks the galloping horse and allow study of the movements fluidity and the individual images allow study of the stages in the movement. This could lead to speculations on how to better ride a galloping horse, or develop a more suitable saddle. Or animation: transfer this understanding of the galloping motion to other object or mimicry of the gallop in a different media. This access to manipulation of motion is what led to the magical surprises in trick film and animation.

Weta workshop from New Zealand have developed a fully computer animated horse model. The model is literally done inside-out[59]. This is current state of the art horse-animation, as started by Eadweard Muybridge.

Price (1964) pointed to scientific curiosity as the factor to be satisfied by the camera and motion-pictures: building models that explores and manifests hypoteses about the surrounding world. Wells (1998) also point at scientific curiosity and a technological (and businessoriented) race for utilising the novel camera technology. Muybridges photos are an god example of this bonded purpose and drive. As Wells (1998) points out: "the very *craftsmanship* of the animated film became its inhibiting factor at a time when the immediacy of the photographic image was its novelty and its passport to industrial legitimacy …" (Wells, 1998, p. 2). Cinematography became the favourite motion picture technology for the profit-focused industrial societies and a tool for scientifc investigations and documentation. Animation, in the sense of manual manipulation of the contents of the individual image, continued in the context of trick-movies and graphic artistery like Gertie The Dinosaur.

The motivating factor for the persistence of animation as an expressive force became entertainment and later information. The Disney studios not only produced Bambi and Mickey Mouse, but also instructional and propaganda movies in cooperation

[59] youtube.com/watch?v=YncZtLaZ6kQ Animator Richard Williams horse animation guidelines is also recommended: youtube.com/watch?v=INQx-Lzs8mU (Both videos accessed October 2016).

with the US Army during WWII. Animation experienced the socalled *Golden age* during the 1930'ies and until the late 1960'ies.

The camera and cinematography made animation possible as examplified by Gertie The Dinosaur. Camera technology also liberated animation form a purely graphic incarnation as anything that can be photographed can also be turned into animation by sequencing slightly different images. This has has provided an artistic freedom in materials used for creating animated products. The camera enabled the exploration of new creative spaces within animation. Materials provide restrictions and possibilities to the expressiveness of the animation product, and animation has found many outlets in terms of materials. As noted by Stephenson (1973): Only imagination restricts the animator. Examples are cut-outs (Gilliam, 1969), sand (Leaf, 1974), clay (Aardman, 2007), celluloid filmstrip (Mclaren, 1955), and furniture (PES, 2008)[60]. Materials, techniques and production processes is a subject in its own right, but (Furniss, 2008a and 2008b) provide solid introductions to these subjects. The installment of lifelike attributes via motion, is not restricted to a certain material.

Digital technology represents the latest technological development in the history of animation (Wells & Hardstaff, 2008). The intertwined trajectories of interst in movement as an existential and scientific phenomenon that drove the development of cinematography got seperated into "moving images" and "animation". But digital technologi appear to have brought the moving image and animation back together to a degree where "… cinema can no longer be clearly distinguished from animation" (Wells & Hardstaff, 2008, p.5). The digital technological platform has established a common format for these two incarnations of simulating movement that allow a seamless integration of magical surprises along the enire scale of mimicry. The consequence is that "Digital technologies are dissolving the borders between disciplinary forms. Animation techniques have been widely adopted by other cultural production areas from art to science" (Wells & Hardstaff, 2008, p.184). Defining and researching animation based on the animated form therefore no longer makes sense as it is the context and purpose that defines the form, not the material or the media.

The TPFD-model and proposed contextual definition of animation therefore also support the historic status of animation.

Adding to the widespread use of animation in established contexts of science and paractice is also the socalled democratisation of animation (Wells & Hardstaff, 2008). Camera-toting digital tablets and mobile phones have crept into everyone's possession during the past decade and enabled everyone to create animated products and share them on Youtube, Vimeo, Twitter, Instagram, etc.. A new era of animation is happening.

[60] Adult content.

This era began in the 1960'ies when the development in digital computer technology started accelerating. One aspect of this development was the development of user interfaces to give users access to and control of these magical information devices.

The following section address the relationship between interactive digital systems and animation. This account is an extension to the established history of animation and an aspect in establishing functional animation.

18.3 Functional animation

This section presents the history of the computer user interface in the perspective of movement: when, who and why did movement become part of designing human computer interaction. From this account it wll be apparent how movement and animation has been part of animation history and visa versa) since the mid 1960'ies and thus creating the overlap represented by functional animation.Table 9 provide a chronological overview of the parallel historic development within animation and interaction design. The timeline contain three zones between first, second and third wave HCI[61] (Bødker, 2006, 2015). These zones indicate gradual changes in the presence of digital technology within human activities. I have added a fourth zone around 1963 named "the dawn of HCI" as Donald Sutherland consciously incorporated many features in consideration of how a human actor could better utilise the functionality of the Sketchpad system (Sutherland, 1963). Before Sketchpad, computer technology development was primarily an engineering activity. Visions of computer human relationships like those formulated by Vannevar Bush in 1945 (Bush, 1945) did exist and inspire, but Sketchpad was the first incarnation of a use(r)-centered system. The commencement of first wave HCI is by Bødker (2006) positioned around the development of Xerox Smalltalk. The periode is characterised by a focus on "cognitive science and human factors" (Bødker, 2015, p.24) and research aimed at rigid guidelines for uniform design outcomes. Usability became the aim of professional interaction design. Second wave HCI moves the user into a role of actor and methods become participatory and the social dynamics around systems, in particular in the context of work, are in focus. Contextual design, workshops and prototyping grew out out of these years. Third wave maintained the contextual understanding and methods, but "… challenged the values related to technology in the second wave (e.g., efficiency) and embraced experience and meaning-making" (Bødker, 2015, p.26). UX-design has taken in usability, and explorative research methods for researching emergent uses which reflect the

[61] HCI is Human Computer Interaction. I have not within this dissertation distinguished between HCI and Interaction Design. In the perspective of Bødker (2006, 2015) I believe the two concepts to reference the same practice which over time has evolved from HCI to Interaction design. However, Rosenfeld, Moville and Arango (2015) distinguish between Information Architecture and Interaction design. In practice, these design activities are popularly referred to as UX-work; which is a reference to Bødkers third wave focus on product functions beyond the feature-level.

ubiquity of computing both in terms of technological platforms, but also contexts of use has emerged. Computer usage is in third wave HCI not confined to work or private practice, nor any particular age group or other demographic value.. Bødker (2015) leaves it to others to contemplate fourth wave HCI. Guesses could be quantified self, pervasive datadriven computing and content as interface via adaptive data visualisations could be contenders in unison with VR, AR as an integrative and immersive computing paradigm. Methodologically then data granularity, intensity and possible points of intervention within the physiological aspect of experience and human performance may transform the approach to empirical studies.

Animation	Year	Animation in Interaction Design
Georges Méliés: A Trip to the Moon	1902	
J.S Blackton: Humorous phases of funny faces	1906	
Winsor McCay: Little Nemo in Slumberland	1911	
Winsor McCay: Gertie the Dinosaur	1914	
Winsor McCay: The Sinking of the Lusitania	1918	
Fernand Léger: Ballet Méchanique	1924	
Walt Disney: Steamboat Willie	1928	
Oscar Fishinger: Experiments in Hand Drawn Sound	1932	
Oscar Fishinger: Kreise	1933	
Walt Disney: The Band Concert	1935	
Walt Disney: Snow White & The Seven Dwarfs	1937	
Walt Disney: Pinnocio	1939	
Walt Disney: Fantasia	1941	
Walt Disney: Bambi	1942	
Norman McLaren: Hen Hop	1943	
	1944	
	1945	Bush (1945)
UPA: The Brotherhood of Man	1946	ENIAC (Electronic Numerical Integrator And Computer)
Oscar Fishinger: Motion painting #3	1947	
	1948	Oscilloscope based missile game
Ray Harryhausen: The Best from 20.000 Fathoms	1953	
	1958	First computer game: Tennis for Two
Hanna Barbera: The Flintstones	1960	

	61	
	62	
	-- Dawn of HCI --	
Ray Harryhausen: Jason and the Argonauts Edward Zajac, Bell Labs: A Two Gyro Gravity Gradient Attitude Control System	63	Sketchpad (Sutherland, 1963)
	64	
	1965	
	66	
Norman McLaren: Pas de Deux	67	
	68	NLS Demo by Douglas Engelbart
	69	GENESYS by Ronald Baecker (Baecker, 69)
	1970	Xerox PARC established
Peter Foldes: Metadata (based on drawings interpolated digitally)	71	
	72	First Smalltalk-72 program runs. Alan Kay plan animation in UI (Kay, 1993)
	-- First Wave HCI --	
Michael Chricton: Westworld (Digital image processing)	73	Xerox PARC Alto (Smalltalk WMP UI)
	74	
	1975	
	76	
	77	Smalltalk-76: First complete running system
	78	Xerox NoteTaker “laptop” w. Smalltalk
	79	
	1980	
	81	Xerox STAR released w. Smalltalk-80
Steven Lisberger: Tron	82	
	83	Apple LISA released Smalltalk released officially Article on Animation in BYTE (Heckel, 1983)
(Thomas & Johnston, 1984) Disney studios 1st comp. anim.: Wild	84	Apple Macintosh released

Thing		
John Lasseter/ PIXAR: The Adventures of André and Wally Bee	1985	Microsoft Windows 1.0 released
John Lasseter/ PIXAR: Luxo Junior PIXAR founded: Steve Jobs buys The Graphics Group from Lucasfilm	86	UNIX X released Self developed at Xeroc PARC
	87	
Robert Zemeckis: Who Framed Roger Rabbit	88	
James Cameron: The Abyss (ILM)	89	Animated GIF spec is released
Disney Studios: Rescuers Down Under (scanned drawings)	1990	Public release of Self Baecker, and Small (1990)
	91	
	92	
	-- Second Wave HCI --	
Steven Spielberg: Jurassic Park (ILM) Henry Selick: Nightmare Before Christmas	93	Chang, and Ungar (1993) Kay (1993)
Disney Studios: The Lion King	94	
PIXAR & Disney Studios: Toy Story	1995	Microsoft “Clippy” personal assistant
	96	Macromedia Flash for web (FutureSplash in 1995)
PIXAR & Disney Studios: A Bugs Life John Kricfalusi: The Goddamn George Liquor Program (Adobe Flash cartoon series)	97	Bartram (1997)
	98	
BBC: Wlaking with Dinosaurs series PIXAR & Disney Studios: Toy Story II Wachowski Brothes: The Matrix (bullet time)	99	
Disney Studios: Dinosaur	2000	
Peter Jackson: Lord of the Rings I Hironobu Sakaguchi: Final Fantasy: The Spirits Within (MoCap)	01	Thomas, and Calder (2001) Mac OS X ver.10.0 “Cheetah”, Aqua UI
Peter Jackson: Lord of the Rings II	02	
Peter Jackson: Lord of the Rings III Wachowski Brothes: Matrix reloaded (virtual camera)	03	
	-- Third Wave HCI --	
	04	
	2005	

Disney Studios buys PIXAR	06	Hans Rosling, TED Talk: The best stats you've ever seen
	07	Apple iPhone & iPod Touch Google Android
	08	
James Cameron: Avatar	09	Microsoft Zune HD Music Player (Metro-like UI)
	2010	Apple iPad Windows Phone 7 w. Metro UI Eikenes (2010)
Steven Spielberg & Peter Jackson: Tintin	11	Harrison, Hsieh, Willis, Forlizzi, and Hudson (2011)
	12	
	13	Apple iOS 7
	14	Google Material Design HTML5 released
	2015	Apple Watch
	16	
	…	

Table 9. A parallel timeline of events in animation and interaction design with a particular focus on movment. References to texts addressing functional animation are inserted.

Bødkers observations of first, second and third wave HCI are reflected in the research and usage of movement. The literature review (section 6) and the timeline (Table 9) include a few publications and events from around the ”dawn of HCI”. These would probably appear in most accounts of interaction design history, but they also commence the story of functional animation. The history of interaction design is intertwined with the history of animation from two perspectives: 1) Digital technology has become the defacto platform for production, distribution, execution and consumption of animation. A technological development which has also brought with it a revival of the animate form. Animation is now an integrated part of most digital media. 2) The use of movement as part of creating more efficient and appealing human computer interaction. A use of animation which by the accounts in this dissertation represents functional animation and a historically novel use of animation.

Interaction design Scholar Ronald Baecker is an example of this historical connection; if not being *the* connection. He developed GENESYS (Baecker, 1969) which was one of the first fully digital animation systems (except distribution and consumption in a theatrical setting). Digitally based animation was later fully developed by Lucasfilm Computer Division and John Lasseter. After GENESYS Baecker brought his animation knowledge into the design of human computer interaction when being part of the Xerox PARC Smalltalk development team where animation was intentionally integrated into in assistance of animator Eric Smith (Kay, 1993).

The following sections describe the history of functional animation in relation to Bødker's three waves of HCI.

18.3.1 Dawn of HCI

Movement has been part of the human computing relation since an oscilloscope in 1958 was used by William Higinbotham for the first fully computerbased game[62]. But the start of functional animation is early 1963 when Ivan Sutherland as part of his PhD project developed ”SketchPad” (Sutherland, 1963a).

Sketchpad allowed CAD-style drawing on a computerscreen (oscilloscope) with a lightpen. The Sketchpad system allowed creation, but also zooming, panning, re-positioning, rescaling, re-shaping and rotation of screen-objects, in both 2D and 3D, – all with real-time screen updates: "If the user moves one vertex of a polygon, both adjacent sides will be moved. If the user moves a symbol, all lines attached to that symbol will automatically move to stay attached to it". (Sutherland, 1963a, p. iii). Sketchpad[63] allowed all the fundamental manipulative actions and dynamics found in the interaction of a 2014 touch-interface. But the Sketchpad had no on-screen system-controls (except the lightpen-pointer). All function controls were physically present as dedicated buttons and switches outside the screen. The interface had no functional abstractions and representations as we see them in the various screenbased GUIs of today. The system was metaphorically a "virtual" piece of paper allowing creation, manipulation and integration of basic graphic shapes with a "magic" pen. In that perspective, Sketchpad represents an example of how movement is an important component for emulating properties of the physical world in a computer system. But also how ”magic features” like infinte zooming, replacement, scaling and immediate duplication of forms is possible in a digital environment. Sketchpad is referenced by Simon (1996, p.133) as an example of digital representation and manipulation of objects in space (and by my inclination, therefore also time) for solving design problems related to the issues represented by these objects.

[62] In 1948, the “Cathode-Ray Tube Amusement Device” was patented, but it required paperoverlays to the screen and does therefore not qualify as fully computerbased. www.bnl.gov/about/history/firstvideo.php (accessed October 2016).

[63] Demonstration of Sketchpad: youtube.com/watch?v=USyoT_Ha_bA . The intro-speech is almost an introduction to computing anno 2015. I recommend watching both part 1 and part 2 (accessed October 2016).

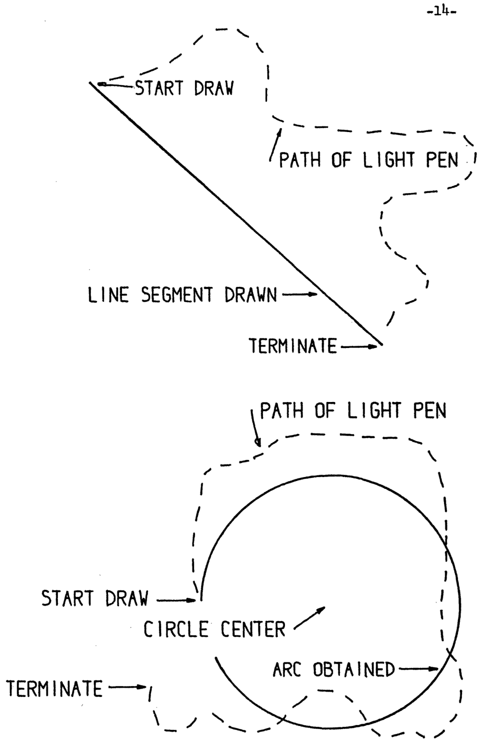

FIGURE 1.4.
LINE AND CIRCLE DRAWING

Figure 47. Illustration of corrective and supportive actions performed by Sketchpad. The lines will "snap" into place when the user indicates completion of the drawing action (Sutherland, 1963a, p.14).

Sketchpad demonstrated and researched the potential of a vision for human-computer interaction that was quite contrary to the then prevailing calculation focused and Command Line interaction approach to computing. Sketchpad is described as allowing for the computer and human to collaborate on solving design-problems:

> The Sketchpad system makes it possible for a man and a computer to converse rapidly through the medium of line drawings. Heretofore, most interaction between men and computers has been slowed down by the need to reduce all communication to written statements that can be typed; in the past, we have been writing letters to rather than conferring with our computers" (Sutherland, 1963a, p.1).

The possibilities of Sketchpad went even further: "Since Sketchpad is able to accept topological information from a human being in a picture language perfectly natural to the human, it can be used as an input program for computation programs which require topological data, e.g., circuit simulators" (Sutherland, 1963, p.iii). The open programming principles of Sketchpad preceded the later invention of object oriented programming at Xerox PARC as the Sketchpad system was based on an abstract representation of the properties of the graphics that it enabled the user to create and manipulate. Sketchpad was a dynamic direct manipualtion system in the days of batch computing[64]. The trajectory for human-computer interaction laid out by the Sketchpad vision was furthered by Xerox, which, as a photocopier company, feared the paperless office and therefore created the Xerox Parc Research Labs in Palo Alto, California in 1970.

On this trajectory was also ”The mother of all demos”, performed on december 9th 1968 by Douglas Engelbart of Stanford University. The fully integrated NLS, or oN-Line System, showcased hypertext, videoconferencing, remote collaboration, had a mousecontrolled graphic interface with multiple windows, and as told by Engelbart himself: "Any one application could manage multiple windows, and you could easily move objects, paragraphs, and words between them”[65]. The project was funded by NASA and ARPA, and pursued the goal of using digital technology to ”augmenting human intellect” (Engelbart & English, 1968). It is interesting that pioneering computer systems like Sketchpad and the even more revolutionary NLS both incorporate the ability to manipulate the on-screen information representations via movement. Why should windows have motile properties, like repositioning and resizing? and why should it be possible to manipulate the elements created in Sketchpad. There are no references to integration of movement from considerations of: ”wonder what would happen if we make this object scalable?”. Engelbarts project could be seen as an example of research through design and thus the inclusion of movement has happened because it ”made sense”: Windows take up screen space, therefore they must be motile to allow the user to prioritise which content to dominate the screen. Which is also an example of user centered design. Movement appear to have been included because movement is a fundamental and unavoidable component of any design that has a dynamic character. It is the quality of motility to obtain a useful interface that made movement part of these solutions. Which is also the results of later studies like Chang and Ungar (1993) Thomas and Calder (2001). These studies contnue the attempt at augmenting human intellect by establishing empirical studies that show how motile qualities offload the intellectual

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[64] Ivan Sutherland went on to form Evans & Sutherland which originally focused on simulation of flight, and 3D graphics creation and manipulation in general, but this business was sold off in 2006, and E&S is now the world leading providers of fulldome digital theatre systems. www.es.com/About/History.html (accessed October 2016).

[65] In an interview with The Register: www.theregister.co.uk/2008/12/11/engelbart_celebration/ (accessed October 2016).

effort in understanding the interface and allow maintenance of focus on the task. But that is second wave HCI.

The NLS system lay the foundation for the personal computer and development of the GUI: ”Many radical new ways of matching the dynamics of our[66] symbol structuring to those of our concept structuring are basically available with today’s technology. Their exploration would be most stimulating and potentially very rewarding” (Engelbart, 1963, p.20). and ”direct manipulation” by the mouse was also established following extensive tests of five alternatives: Grafacon, Joystick, Mouse, Knee Control and Light Pen (English, Engelbart & Berman, 1967). ”Inexperienced subjects did not perform quite as well with the mouse as with the light pen and knee control, but experienced subjects found the mouse the "best" of the devices tested, and both groups of subjects found that it was satisfying to use and caused little fatigue” (English et al., 1963, p.13). But final selection of the mouse and thus establishment of the present day WIMP GUI did not happen until the Xerox PARC Learning Research Group or ”Smalltalk team” led by Alan Kay selected this poining device. In his 1969 dctoral thesis, Alan Kay refers to a ”stylus” as pointing device.

Baecker (1969) used an ordinary pen on a tracking plate for sketching drawings into the GENESYS system. This had the added possibility of allowing a piece of paper to be put on the plate and capture an analgue version of the drawing being digitized. GENESYS was a fully digtal animation program and like Knowlton (1964) then Baecker (1969) show how efforts in using computer technology for both computer assisted and computer generated animation existed in parallel to the progression in development of human computer interaction. Baecker’s career took him into user interface design and a lasting imprint was his and Ian Smalls joint 1990 bookchapter on ”Animation at the Interface” (Baecker & Small, 1990), which, considering his development of GENESYS and later involvement with the Smalltalk team is the earliest documented link between an understanding of animation and an understanding of interaction design. Both GENESYS and Sketchpad were developed at the MITs Lincoln Lab[67].

In 1993 Alan Kay made a presentation on the early history of Smalltalk (Kay, 1993). In this he describes the following events at the Xerox PARC Learning Research Group: ”Bill English[68] was still encouraging me to do more reasonable appearing things to get higher credibility, like making budgets, writing plans and milestone notes, so I wrote a plan that proposed over the next few years that we would build a real system on the character generators cum NOVAs that would involve OOP, windows, painting, music, animation, and "iconic programming"” (Kay, 1993, p.

[66] ”our” as in ”humans”.

[67] A tribute page to the Lincoln Lab is managed by Bill Buxton. billbuxton.com/Lincoln.html (accessed October 2016).

[68] Bill English co-published on the NLS with Douglas Engelbart (Engelbart; & English, 1968).

532). The inclusion of movement into Smalltalk was thus part of a conscious strategy and on the same agenda as the development of Object Oriented Programming. The motivation for Smalltalk was to create the *Dynabook* – a computer for ”Children of all ages”. A vision that could links to the ”augmentation of human intellect” ambition by Douglas Engelbart and Steve Job’s infamous metaphor of the computer as a ”bicycle for the mind”[69]. Thus the GUI was conceived on the basis of a computersystem developed with children in mind. And movement was part of this vision.

FIGURE 11.27 Children with Dynabooks from “A Personal Computer for Children of All Ages” [Kay 1972]

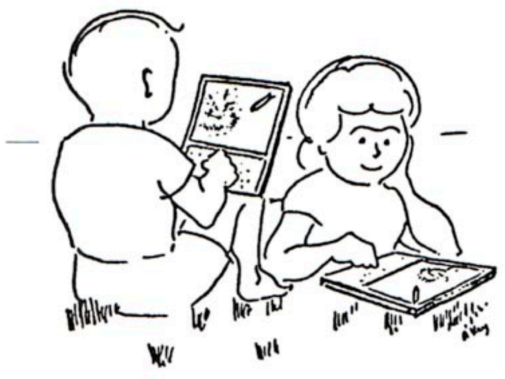


Figure 48. An early vision for the Dynabook (Kay, 1993).

To realise the ambition of movement in the interface an expert was brought in:

> The animations on the NOVA ran 3-5 objects at about 2-3 frames per second. Fast enough for the phi phenomenon to work (if double

[69] In an interview for a documentary about the US Library of Congress Jobs metaphorically called the computer "a bi-cycle for our minds" (Lawrence, 1990). The interview has no date, but Jobs is credited as President of NeXT so the interview is between 1985 and 1990. The following is a full transscript of Jobs statement: “I think one of the things that really separate us from the high primates is that we’re tool builders. I read a study that measured the efficiency of locomotion for various species on the planet. The condor used the least energy to move a kilometer. And, humans came in with a rather unimpressive showing, about a third of the way down the list. It was not too proud a showing for the crown of creation. So, that didn’t look so good. But, then somebody at Scientific American (ML: Wilson (1973)). had the insight to test the efficiency of locomotion for a man on a bicycle. And, a man on a bicycle, a human on a bicycle, blew the condor away, completely off the top of the charts. And that’s what a computer is to me. What a computer is to me is it’s the most remarkable tool that we’ve ever come up with, and it’s the equivalent of a bicycle for our minds” (ML transscript).

> buffering was used), but we wanted "Disney rates" of 10-15 frames a second for 10 or more large objects and many more smaller ones. This task was put into the ingenious hands of Steve Purcell. By the fall of '73 he could demo 80 ping-pong balls and 10 flying horses running at 10 frames per second in 21⁄2D. His next task was to make the demo into a general systems facility from which we could construct animation systems. His CHAOS system started working in May '74, just in time for summer visitors Ron Baecker, Tom Horseeley, and professional animator Eric Martin to visit and build SHAZAM a marvelously capable and simple animation system based on Ron's GENESYS thesis project on the TX-2 in the late sixties (Kay, 1993, p. 539-540).

Ronald Baecker who had developed the GENESYS system was ”brought in” to help implement the animation feaures of Smalltalk. From this description it appears as if animation has two incarnations in Smalltalk: 1) as a ”systems feature” and 2) as a stand alone program to allow users to create animation. The two views are not mutually exclusive, but it is the first that is interesting to functional animation. In favour of this is Baecker (1973) which describes his efforts in utilising the ability of animation to manipulate time and space in an ”… effort in program animation, the use of computer animation to visualize the dynamic abstractions of computer science … testing the understanding with short expereimental film clips” (Baecker, 1973, p.4.4). Ronald Baecker is later in Kay (1993) credited for his ”highly valuable contributions” in realising the user interface vision of:

> … an apparently free environment in which exploration causes desired sequences to happen (Montessori); one that allows kinesthetic, iconic, and symbolic learning - “doing with images makes symbols" (Piaget & Bruner); the user is never trapped in a mode (GRAIL); the magic is embedded in the familiar (Negroponte); and which acts as a magnifying mirror for the user's own intelligence (Coleridge) (Kay, 1993, p. 553).

The kinetic element refers to the motile properties of the final Smalltalk system, and thus the WIMP GUI. In his historic account Alan Kay however express his frustration about having seen this vision wither in reality of 1980 corporate Xerox focsed on workstations: ”By this time I was both happy about the cleanliness and elegance of the Smalltalk conception as realized by Dan[70] and the others, and sad that it was farther away than ever from the children—it came to me as a shock that no child had programmed in any Smalltalk since Smalltalk-76 made its debut.” (Kay, 1993, p.560)

Eric Martin is THE animator of Smalltalk and Ronald Baecker the bridge between animation and interaction design. Eric Martin joined Baeckers GENESYS project from the Harvard Carpenter Center for the Visual Arts and Cambridge Design Group and provided professional guidance to Ronald Baecker for the development

[70] Dan Ingalls. Ingalls (1978).

of GENESYS. He has a one-page statement in (Baecker, 1969) of why a computer is "… ideally suited to making animation "possible" through the fluid refinement of these changes" (Baecker, 1969, p.20) - . Eric Martin must also have had an impact on the Smalltalk animation integration since Alan Kay mention him by name.

Animation is the graphic art which occurs in time. Whereas a static image (such as a Picasso or a complex graph) may convey complex information through a single picture, animation conveys equivalently complex information through a sequence of images seen in time. It is characteristic of this medium, as opposed to static imagery, that the actual graphical information at any given instant is relatively slight. The source of information for the viewer of animation is implicit in picture change: change in relative position, shape, and dynamics. Therefore, a computer is ideally suited to making animation "possible" through the fluid refinement of these changes.[4]

Eric Martin

Carpenter Center for
the Visual Arts,
Harvard University,
and
Cambridge Design Group, Inc.

Figure 49. Dedication in Baecker (1969) from Animator Eric Martin. The definition of animation as "graphic art which occurs in time" is quoted in Baecker and Small (1990).

The development of Smalltalk73 also moves history of HCI into the first wave. This is also where we leave Eric Martin and any other explicit mention of animators in the interaction design literature – apart from the mention of "an experienced animator to do the animations" in Baecker, Small and Mander (1991, p.2).

18.3.2 First wave HCI

By 1979, Alan Kay was somewhat disillusioned. Smalltalk had succeded, but the Dynabook vision was not acknowledged by Xerox management. But the system was a success and apparently popular and demos were given, some of which have entered computer mythology:

> By now it was already 1979, and we found ourselves doing one of our many demos, but this time for a very interested audience: Steve Jobs, Jef Raskin, and other technical people from Apple. They had started a project called *Lisa* but weren't quite sure what it should be like, until Jef said to Steve, "You should really come over to PARC and see what they are doing." Thus, more than eight years after

> overlapping windows had been invented and more than six years after the ALTO started running, the people who could really do something about the ideas, finally got to to see them. The machine used was the Dorado, a very fast "big brother" of the ALTO, whose Smalltalk microcode had been largely written by Bruce Horn, one of our original "Smalltalk kids" who was still only a teen-ager. Larry Tesler gave the main part of the demo with Dan sitting in the copilot's chair and Adele and I watched from the rear. One of the best parts of the demo was when Steve Jobs said he didn't like the bit-style scrolling we were using and asked if we could do it in a smooth continuous style. In less than a minute Dan found the methods involved, made the (relatively major) changes and scrolling was now continuous! This shocked the visitors, especially the programmers among them, as they had never seen a really powerful incremental system before (Kay, 1993, p.560).

This is Alan Kays description of the infamous demo where Apple and Steve Jobs were hiven proof of concept and inpiration to further the development of the Lisa and the MacIntosh. In the functional animation perspective it is a noteworthy anecdote that Steve Jobs actually influenced some of the motile properties of Smalltalk, and thus probably got inspired to how movement should work in the Apple products.

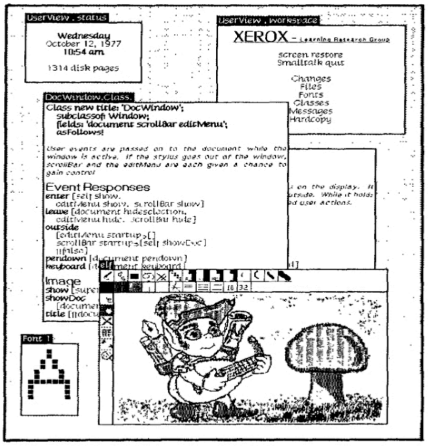


Figure 3. Painting a picture

Figure 50. Smalltalk was the first incarnation of the WIMP GUI (Ingalls, 1978, p.11)

The Apple LISA (released 1983) was the first commercially available computer to have a WIMP GUI. The LISA was followed in 1984 by the MacIntosh that had an improved version of the WIMP GUI. The WIMP GUI was based on the desktop metaphor and inspired by the Xerox STAR and Smalltalk platforms, but improved (quite a lot) by respectively the LISA and the MacIntosh team led by Jeff Raskin. Both of these UIs incoporated movement in the interface: draggable windows, resizing of windows, motile icons (drag n' drop), drop-down menus, buttons and a mouse pointer (called a "bug" by Engelbart). The trademark UI features are also reflected in the WIMP abbreviation as each element: Windows, Icons, Menus and Pointers reflect a motile property.

The incarnations and influence of Smalltalk is illustrated by Figure 51. The Smalltalk UI concept remained influential throughout the entire first wave of HCI as examplified by this 1993 statement: "The current state-of-the-user in GUIs centers on the debate between basically similar interface standards. Popular GUIs such as Windows, Macintosh, Motif or OpenLook are basically more similar than dissimilar" (Mandelkern, 1993, p.38). An analysis which in those years was being met by the shift in view upon computer users to actors and participants in the design process, as second wave HCI methods gained traction.

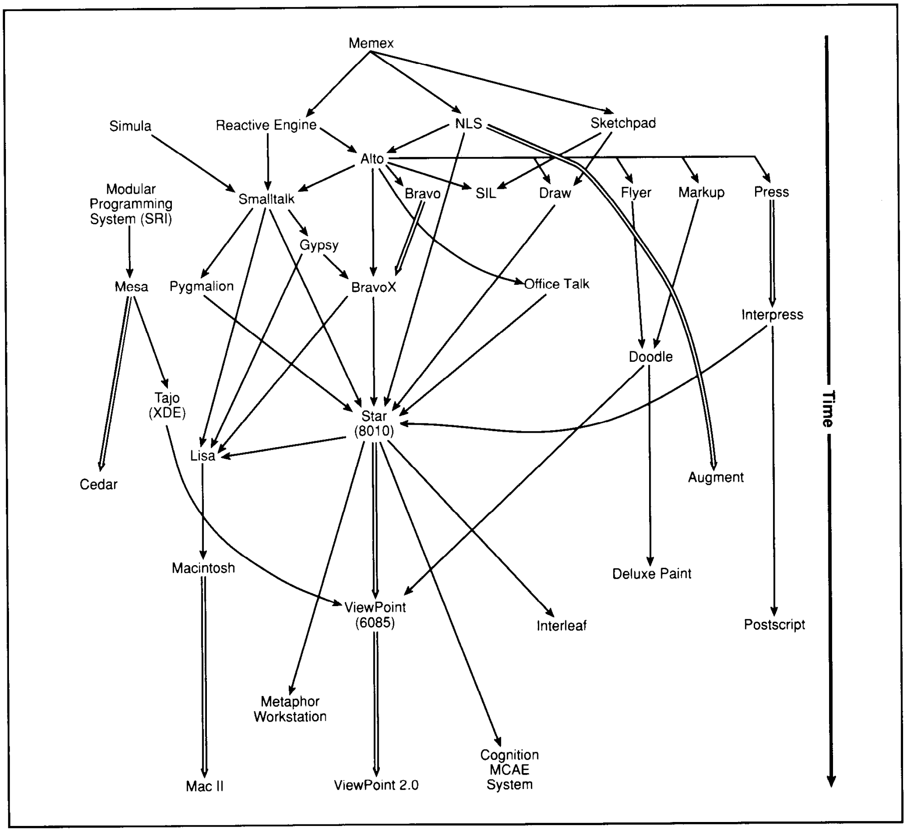


Figure 8. How systems influenced later systems. This graph summarizes how various systems related to Star have influenced one another over the years. Time progresses downwards. Double arrows indicate direct successors (i.e., follow-on versions). Many "influence arrows" are due to key designers changing jobs or applying concepts from their graduate research to products.

Figure 51. Illustration of the system infleunces centered around the Xerox Star (Johnson, Roberts, Verplank, Smith, Irby, Beard, and Mackey, 1989, p. 21).

The first substantial reference to animation as an independent influence within interaction design in first wave HCI is Paul Heckels 1983 article in BYTE Magazine (Heckel, 1983). The article is a chapter from Heckels 1984 book ”The Elements of Friendly Software Design”. Thomas and Johnston (1984) is the source for Heckels understanding of animation as effective communication which he then applies to software development by deducing a set of user centered design principles. The animation principles are introduced in section 19.1: 1) *Make it interesting* is better known as *feedback (*Johnson, 2010). It is based on the idea that a character should always display a motion or an object: ”a piece of business” that forwards the story (Heckel, 1983, p.144). Heckels proposal is to implement a piece of business that lets the user know that the software is working. 2) *Exaggerate Reality* is about utilising animation principle *exaggeration* and caricature to make the software perform better than the reality upon which it draws its reference. The simple example is a spreadsheet (Visicalc) which models a paper spreadsheet, but has far more columns and rows and performs calculations automatically. In this way Heckel anticipates what within the NUI paradigm is referred to as *super real* (Wigdor & Wixon, 2011, p.47). 3) *Think in visual terms* is about viewing software as a visual medium, just like animation, and to communicate as much as possible without spoken/textbased dialogue. Heckel says: ”Commands come later and then only to support the pictures” (Heckel, 1983, p.144). So: Visual communication should take presedence over text. This could be interpretated as an early version of the mobile first principle *content as interface* (Wroblewski, 2011), but as 1983 were the days of WIMP GUI, then this is more likely a pointer to the Icon part of the WIMP principles. 4) *Prepare the audience* is picking up the staging animation principle and proposes to consider ”How should information be structured on the screen?” and ”… think of software as consisting of series of scenes, each of which needs to be staged appropriately” (Heckel, 1983, p.144). Such considerations point to what is now established as *interface design* and *information architecture* – in the terminology of e.g. Garrett (2003). Heckel then proceeds to propose animation principles *anticipation* and *slow in-slow out* to direct the users attention to relevant part or event in the interface. 5) *Don't crowd the screen* is using the animation principle of *secondary action* to point at the design principle better known as *simplicity*: ”Software must be simple, clear and easy to understand” (Heckel, 1983, p.146). The designer must make choises and not put all features at the front. 6) *Involve the audience* is an interesting principle as it builds on descriptions of how the idea for an animation is transferred among different stakeholdes and eventually visualised by the animator and then must be picked up by the audience. This description of how the aim is to install a certain idea, understanding, emotion, etc. via the animation is by Heckel transformed into a usercentered perspective as he says: ”… involve the audience, start with something they know and like, and keep it familiar and appealing” (Heckel, 1983, p148). This principle underlines the general user centeredness in Heckels design approach, but is by the spreadsheet example (Visicalc) also an argument for skeumorphism which takes the notion of familiar and appealing a bit too far by todays design standards.

Heckel also turns his attention to the software development process and compares it positively to the development of animation: ”The making of a Disney movie was a constant process of prototyping, revising, and rewriting” (Heckel, 1983, p.148) and ”Find problems and pleasant surprises as early as possible” (Heckel, 1983, p. 150). But the perspective is that of the animator and the program designers and thus the process and tools must also enable a ”best guess of what the audience’s experience will be” (Heckel, 1983, p. 150). Heckel is user centered, but the development processes had not yet developed the notion of user testing or something as radical as user involvement. As Heckel says: ”… no software designer can get the user interface right the first time” (Heckel, 1983, p. 150). We are still in first wave HCI.

I might have read too many contemporary understandings of interaction design into this text. But it is never the less impressive how Heckels reading of the principles of animation in 1983 lead him to a set of interaction design principles which so easily translates into contemporary principles. This, on the other hand, point to a review of current principles. We are doing third wave design based on first wave principles. In the context of functional animation then it is only principle 1 and 4 that actually concerns motion. The remaining principles address other dimension of interaction design.

In parallel to the first wave of HCI was the development in computer animation. The stories overlap concretely in the story of Steve Jobs. Whether they overlap professionally is not apparent from the available literature.

Pixar is the company that established and proved that digital 3D technology could be used to create animated feature films, on par with what Disney had accomplished through analogue animation techniques. The milestone 2 minute film “Luxo Jr.”, was released in 1986 and is the first animated digital 3D movie to be nominated for an Oscar for Best Animated Short Film[71]. In 1988 “TinToy” wins the Oscar for Best Animated Short Film. In 1995 “Toy Story” is released to popular and critical acclaim. “Toy Story” is the worlds first fully digital animated 3D feature film and it is nominated for several awards, among these an “Original Screenplay Oscar”.

Pixar was originally the Lucasfilm Computer Division and consisted of a talented group of computer graphics engineers and a single animator named John Lasseter. John Lasseter was employed in 1984 (same year as the Apple MacIntosh was released) by the title “Interface Designer”, so as not to raise management suspicion about activities and competencies that were not directly aimed at the engineering aspects of their work (Isaacson, 2011). John Lasseter also recall the manouver: “Then Ed (Catmull, ML) asked if I wanted to "do a little freelance" at Lucasfilm – although he couldn’t be seen to be hiring an animator as that wasn’t really what they did. So he called me an ‘Interface Designer’. Nobody knew what that was, but they didn’t question it in budget meetings!” (Day, 2009). An interesting anecdote in several ways: one being that the title was established and the relevance for

[71] Notice that it is actually two animation firsts: Both digital and 3D.

development of computer systems was recognised in the computerdevelopment mileu, and that Johan Lasseter apparently knows (or knew?) about this type of work. Another perspective being that the management of the computer division recognised the need for an artist to challenge and supervise the technical direction and ambitions in an engineering and technology development group (Paik, 2007). Prior to being employed by Pixar Lasseter recognised the potential in computer animation and was discharged from Disney due to his headstrong persecution of this appraoch to animation. Something Disney later regretted a whole lot.

George Lucas recognized the long term value of what the Computer Division group was working with, and did use their capabilites, including Lasseters animator skills for a few projects. But for a variety of reasons Lucas film wanted to sell off the group. Long before being sold off, then the people in the group were aiming at producing a feature length digitally animated film – an ambition that the rest of the world later has gotten to know as “Toy Story”. An an ambition that Jobs knew about when he acquired the group.

In 1985 Steve Jobs was kicked from Apple by John Sculley and did not hesitate to start NeXT computing, which was years later integrated into Apple when Steve Jobs came back as interim CEO. The NeXT Unix-based SW is now at the core of Apples OSX operating System. Even before being kicked, Jobs recommend to Apple the acquisition of the Lucasfilm Computing Division, but this did not happen. Even Ed Catmull of the Lucasfilm Computing Division did not see the link between a computer company, like Apple, and their work in digital 3D graphics and computer animation. But Jobs did, and in February 1986 he acquired the LucasArts Computing Division and set it up as Pixar, independently of NeXT computing:

> I truly believed that computer graphics – and I had some experience with that in a 2-D form – could be used to make products that would be extremely mainstream. Not tangible, manufactured products, but something more like software – intellectual products. It just made sense to me. And what I saw at Pixar was some amazing computer science and the possibility of that being used in an even more artistic fashion than I'd ever been involved in. So I was very excited. … What's more, I could see computing power exploding exponentially over the next decade. But hardly anyone I knew had any idea of exactly what they were going to do with all that power. And I saw Pixar was a black hole for computing power. So I liked that too. (Paik, 2007, p.51-52).

Apple is renowned for its graphics performance, focus on look n' feel and trendsetting consumer electronics and Pixar Animation Studios spearheaded the development of digital character animation during the 1990'ies and is still releasing impressive animated features on a regular basis. These matters in themself make the companies remarkable and interesting as representatives of each their field. The companies have a common focus on excelling in expressiveness and advanced technology and from 1997 till 2006 Steve jobs held parallel positions as CEO of both Apple and Pixar. Pixar and Apple also share a common history and understanding of their respective fields: The combination of Technology and Art. User expectations to computers and handheld devices were never the same after Apple created the MacIntosh and the iPhone, and animated film has by the products of Pixar become as recognised as in the golden age of animation between 1930 and 1970. The Apple product line is together with Bill Gates and Microsoft Windows two of the most influential endeavours in 21st century computing and has led to the common (main stream) conception of what is to be expected of personal computing - how humans interact with computers, how digital phenomena are represented and how phenomena are represented digitally.

In line with the thoughts of Kay (the Dynabook) and Engelbart (augmenting mans intellect), then Apple came to realise the vision for computing that started the first wave of HCI and which is probably still driving developments in human computer interaction. Apart from engineering “advanced calculators”, then the early work in computers also had a humane vision: “A few years later, in the early 70’s … The workers at PARC also believed as I did, that human usability was more important than the traditional concerns of computer science at the time: execution speed and the efficient use of memory” (Raskin, 1994, p.13). Steve Jobs became the individual to personify and bring these new age visions to commercial success, right up the 21st century.

The level of animation implemented into contemporary Apple OSX and iOS is not haphazard (Apple, n.d.a, n.d.b), and the personal connection between Pixar and Apple makes it easy to speculate about any influence. But apart from Steve Jobs, the employment of Ronald Baecker and Ian Small at Apple (Baecker & Small, 1990; Baecker, Small & Mander, 1991) and John Lasseter’s wife’s employment at Apple, then no concrete connections are available in literature.

In 1990 Ronald Baecker and Ian Small contributed to '*The Art of Human-Computer Interface Design*' edited by Brenda Laurel, with a text titled '*Animation at the Interface*'. The text is explorative and many fundamental perspectives upon functional animation are brought out. Baecker and Small (1990) suggest three major uses for animation in user interfaces: 1) Structure, 2) Process, and 3) Function. *Structure* and *Function* are identical to the proposed purposes of interactive animation (section 17). *Process* is better categorised as a usage of functional animation within particular types of user interfaces.

Animation of structure is about the use of animation to build and explore complex digital environments. They propose the ability to change viewpoints and lightning conditions in a CAD environment, and they suggest the possibility of exploring alternative futures which could be animation as a sketching tool for designers (Eikenes, 2010; Vistisen, 2015), and in the same vein they suggest simulating and visualizing dangerous or hard to access areas of an existing or imagined construction. All of these are uses that have been realised today and to these uses we may add first person 3D computer games.

Animation of process is very much focused on the computing dimension of computers as the aim is for animation to be “revealing or explaining complex processes such as computer programs”. (Baecker & Small, 1990, p.256). Becker and Small suggest the construction of visual models to understand what happens when the program executes. The idea appear to build on Baecker (1973) and point to the discipline of interactive datavisualisation which aim at gaining insight into data and data-relations via both representation and interactivity (Fisher, 2010; Ferster, 2013). This area is also the agenda of the development of the ‘cognitive Coprocessor Architecture’ (Robertson, Card & Mackinlay, 1989). As for the direct programmatic intent of Backer and Small, then I suggest viewing the demonstration of “inventing on principle” by former Apple developer Brett Victor where his in editor programming has real time effect. No compile and run. He does this live while programming a game (Victor, 2012).

Animation of function is about the utilisation of animation to make the interfaces of interactive digital systems more comprehensible and aims directly at reducing the complexity of user interfaces by showing what has been done, what can and cannot be done and guide the user as to what to do and not to do. Baecker and Small puts this most eloquently: “Animation can help us review the past, understand the present, and describe the future”.(Baecker & Small, 1990, p.257). This description of how animation is linked to time leads to the formulation of eight concrete roles of animation in (and of) the user interface which all relate to the users timewise position in relation to the task he or she is involved in (Baecker & Small, 1990, p.257-258):

1. Animation as Identification - What is this ?
2. Animation as Transition - From where have I come, to where have I gone ?
3. Animation as Choice - What can I do now ?
4. Animation as Demonstration - What can I do with this ?
5. Animation as Explanation - How do I do this ?
6. Animation as Feedback - What is happening ?
7. Animation as History - What have I done ?
8. Animation as Guidance - What should I do now ?

These eight guiding principles will be further described in section 19.2.

Baecker and Small (1990) are explict on the novelty of *Animation of Function* and talk about the potential of “program illustration” to utilise both animation, video and audio in the future. The term “functional animation” entered my vocabulary during 2011 and could be inspired by Baecker and Small (1990).

Like Norman McLaren and other animators and Thomas (1998) (Table 11), Baecker and Small (1990) emphasize and use constructively the relationship between animation and time as the the possbility of providing the user a better understanding of the user interface, both on a conceptual level, and its practical operation.

Baecker, Small and Mander (1991) takes the narrative aspect of linear animation into the realm of interface icons and basically provides empirical data that show how and why this represents a challenge because information systems are abstract and features do not always have counterparts in physical reality that can be mimicked. However, the example show how movement has been researched as a potential component for the WIMP GUI. The literature review refer to these examples as “cases”.

In parallel to Baecker and Small a group of programmers were developing the Self system at first Xerox PARC and later SUN Microsystems and in 2004, the paper ”Animation - From Cartoons to the User Interface” (Chang & Ungar, 1993) was awarded a ”Most Influential Paper” award by the ACM Symposium on User Interface Software and Technology (Ungar & Smith, 2007, p.37). Baecker and Small (1990) sketch the potential of functional animation and Chang and Ungar (1993) show how and why functional animation should be implemeted in the WIMP GUI. In line with other second wave work, then no structured user tests are performed, but the responses to the implementation are positive. Both in terms of aiding the users in task completion and supporting the interactive experience. The enthusiasm from users made David Ungar proposed measuring the effect of animation by the number of smiles on users faces (Ungar & Smith, 2007, p.25). This was never done, but implies the poitive experience by Self users observed by the creators.

Figure 25. The Self group decides which features to implement in Self 4.0 by voting with candy (late 1994). Each member distributed a pound of candy among various containers according to which features he desired most. We weighed the results and ate the winners (and the losers, too). Left to right: Randall Smith, Robert Duvall (student intern), Bay-Wei Chang, Lars Bak, John Maloney (seated), Ole Lehrmann Madsen (visiting professor), Urs Hölzle, Mario Wolczko, and David Ungar. Not shown: Craig Chambers (who had graduated) and Ole Agesen.

Figure 52. Image from Ungar and Smith (2007, p.33) that gives insight into the atmosphere of the Self research and development environment.

Chang and Ungar (1993) is the first documented attempt at integrating the art of animation via the animation principles into the user interface. The implementation of movement is explicitly based on the application of the 12 principles of animation (Thomas & Johnston, 1984) and Lasseter (1987). The 12 animation principles are categorised into three overall principles of functional animation: *Solidity*, *exaggeration* and *reinforcement*. These principles are described in section 19.1. Chang and Ungar (1993) provide an account of how each principles have affeced the implementation of motile qualites in the Self user interface and conclude: “The overall effect is a more convincing reality, one more likely to capture and retain the engagement of the user” (Chang and Ungar, 1993, p.11). Chang and Ungar (1993) have read Baecker and Small (1990) and understood the relationship between animation and reality as they state:

> Animation provides the visual cues necessary to understand what is happening before, during, and after the action. Unlike user interfaces which burden the user with the responsibility of relying on experience and deductive ability to interpret changes, cartoon animation leverages off of human experience of how objects change and move smoothly in the real world. … Bringing this kind of animation to the user interface has both cognitive and affective benefits. By offloading interpretation of changes to the perceptual system, animation allows the user to continue thinking about the task domain, with no need to shift contexts to the interface domain. By eliminating sudden visual changes, animation lessens the chance that the user is surprised, thus reducing his uneasiness. So employing animation not only aids the user in understanding the events in the user interface, but also makes the user’s experience of the interface more pleasant and comfortable (Chang and Ungar, 1993, p.3)

These observations appear apealing and correct, but Chang and Ungar (1993) do not have any structured empirical data that support these claims, not do they have any references. This is where the study in Part II becomes relevant as it provides the empirical foundation for the effects that Chang and Ungar (1993) and other studies of movement in the interface lack (section 6). This phenomonological study into the meaning of movement in the setting of interactive digital systems establish the basis for the functional and experiential meanings reported by other studies. The only caveat being that the study is performed within a touch interaction paradigm and not the WIMP GUI.

Before both Baecker and Small (1990) and Chang & Ungar (1993) a group at Xerox PARC started devleoping the Cognitive Coprocessor Architecture (Robertson, Card & Mackinlay, 1989) This work concerned experiments in data visualization motivated by ”The graphics capabilities and speed of current, hardware systems allow the exploration of 3D and animation in user interfaces, while improving the degree of interaction as well” (Robertson, Card & Mackinlay, 1989, p.10) and produced a set of 12 information visualization environments (Card, Robertson &

Mackinlay 1991). One of them is the Cone Tree visualization is shown in Figure 53 and was reported in (Robertson, Mackinlay & Card, 1991).

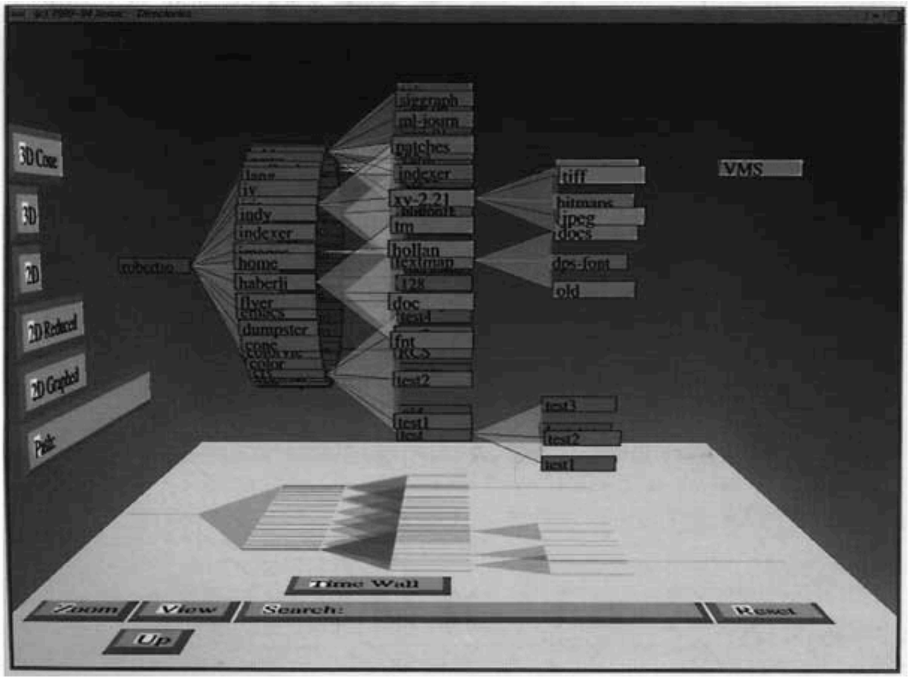


Figure 53. Cone Tree visualization based on the Cognitive Coprocessor Architecture (Robertson, Mackinlay and Card, 1991)

The Cone Tree visualisation is a hierarchical relational set of data where each level is connected to the levels above by strings which establish the cone-shape. The structure is 3 dimensional and the user can interact with the structure by moving it in this simulated space. From the text of Robertson, Mackinlay & Card (1991) it is not clear whether or how the system was tested, but they conclude that "The clearest win in this technology is interactive animation. It is easy to demonstrate that animation shifts cognitive load to the human perceptual system. … Another clear win with interactive animation is the aid it provides in understanding complex structural relationships" (Robertson et al, 1991, p.192) and they not only comment on these gains in usability, but also the improved user experience: "It [interactive animation, ML] also brings the interface and the information to life, making the tasks more enjoyable" (Robertson et al, 1991, p.191). These statements both recognise the effect of motion on the user experience, and establish a difference between the interface and the information accessed via the interface. This demarcation has started to disappear in fourth wave touch screen systems via mobile first design principles like content as interface (Wroblewski, 2011).

Robertson, Card & Mackinlay, (1989) describe how they view animation as ”a very complex and effective discipline for communication” (Robertson, Card & Mackinlay, 1989, p. 11) and by inspiration from Disney animation (Thomas & Johnston, 1984) consciously, and based on understandings of cognition and workflows, implemented movement as part of their systems architectecture, and actually viewed movement as decisive for the success of this access to large data-structures. The Cognitive Coprocessor Architecture thereby represents a conscious decision on implementing movement based on animation as part of establishing human computer interactivity. It is peculiar that the Self team wre doing the same thing in offices in the same buildings at PARC. The motivation however is different: the self team were developing a WIMP GUI and thus addressing first wave challenges to the human computer interaction. The Cognitive Coprocessor team were researching how to re-imagine interaction from the perspective of information; and did so via experiments into data visualizations, data access and and data manipulation. In other words: Information Architecture.

The assumption was, that if smooth motion could be achieved via a clever system architecture, then animation would enable constancy in digital objects. This would correct the sudden shifts in presentation otherwise experienced at state changes. The ecological approach to visual perception supports this line of reasoning: ”To perceive the persistence of surfaces that are out of sight is also to perceive their coexistence with those that are in sight. In short, the hidden is continuous with the unhidden; they’re connected. Separated places and objects are perceived to coexist. This means that separated events at these places are perceived to be concurrent” (Gibson 1979, p.199). The inforamtion visualizations therefore build on these understandings and Card, Robertson & Mackinlay (1991) explicitly build their arguments (among others) on Gibson (1979). Gibson view perception as a active process taking place between the perciever and the environment. The subjects presence and motile behaviour in the environment will gradually reveal properties of the environment to the subject. The environment is to the subject what he percieves it to be and thus vision is not only a matter of light on the retina, but also the subjects active exploration of the environment via his bodily abilities to establish perceptions. Which bring us to the famous quote: ”One sees the environment not just with the eyes, but with the eyes in the head on the shoulders of a body that gets about. We look at details with the eyes, but we also look around with the mobile head, and we go-and-look with the mobile body” (Gibson, 1979, p.211, p.195). This understanding leads to a philosophy for the experimental Information Visualizer environment to support 3D environments in socalled ”Rooms”, and to attempt at making these spaces not only lager (than 2D), but also denser. Leading to a system architecture where: ”By manipulating objects, or moving in space, the user can disambiguate, or zoom in for detail – rapidly accessing more information” (Card, Robertson & Mackinlay, 1991, p.185). This also explains the name for the system architecture. There is an explicit aim and vision of improving the human computer interface by developing better ways of presenting, accessing and manipulating content, and there is researched foundation for exploring the specific approach prototyped via the Cognitive Coprocessor.

As an interesting sidenote, then Card et al. (1991) include a discussion on what they refer to as their exploratory system-building methodology. An approach which by their description has much overlap to what we now refer to as design thinking and research through design, as they describe a non-linear process and ”the particular interplay between synthetic and analytic activities” (Card, Robertson & Mackinlay, 1991, p. 186). In many ways this work was ahead of its time.

Chatty (1992) is yet an investigation into software arcitectures, but he wants to use motion not only for “Identification”, “Demonstration”, and “Explanation”, but also “as part of the data manipulation interface as well” (Chatty, 1992, p.95). Chatty (1992) suggests an alternative understanding of motion and he views motion not as animation, but as a parameter of value in itself that can be added to digital objects. In this sense he locates the discussion of animation in the user interface outside the realm of animation studies and makes the context of functional animation more distinct. Chatty’s view is isnpired by the work on the Cognitive Coprocessor which was still being involved in third generation work on interactive data visualizations (Robertson, Cameron, Czerwinski & Robbins, 2001).

18.3.3 Second wave HCI

Most of the work within second wave HCI relates to software architecture and cases of specific application of motion like zooming (Chui & Dillon, 1997), animated icons (Bodner & MacKenzie) and scrolling (Klein & Bederson, 2005). The most significant work is that of Thomas & Calder (2001) who in many ways repeat the study of Chang and Ungar (1990), but do perform user test on the prototype. This therefore establish a better scientific foundation than that of Chang and Ungar (1993). Thomas & Calder (2001) propose a set of 4 principles based on their own consideration of ”… how a cartoon animator would depict such behaviour” (Thomas & Calder, 2001, p.203). Of course they reference Thomas and Johnston (1984) The principles are: *Attachement*, *reluctance*, *smoothness* and *anticipation*. This work builds on the work done in Bruce Thomas’s PhD (Thomas, 1998), but they also reference Robertson, Card and Mackinlay (1989), Baecker and Small (1990), Chang and Ungar (1993) and others. The principles are presented in section 19.2.

These principles are applied to the object in a drawing editor which is tested via recording of mousemovements and a questionnaire. One respondent states:: “it gives the objects a “feel”. Respondents all respond positively to the movments in the editor and the overall performance efficiency is high. Overal the repondents rated the movemnts positively and agreed that “the manipulated objects seemed to have substance”. However those that had the animation level set to zero also reported a positive experience of the motile aspects. The paper concludes that:

> The effects of animation on the user’s perception of the interface (like the effects of other aesthetic elements such as color) can be profound. On the one hand, this influence suggests that great

> improvements are possible; on the other hand, it warns that equally great disasters can happen. Just as there are good and bad uses of color, so there are good and bad uses of animation. Inappropriately applied, animation will seem childish and drive users away. But sensibly applied, it can make an interface more graceful and enjoyable to use." (Thomas & Calder, 2001, p.220).

The respondentes were "a pool of computer-literate students drawn from the undergraduate and post- graduate programs of the School of Computer and Information Science" (Thomas & Calder, 2001, p.214) included itno the study on a self selected come-first basis.

18.3.4 Third wave HCI

As the field of interaction design grows during the first wave, then publications dedicated to animation/movement, like Heckel (1983) start to appear. The intensity of research and publications grows and steadies until the millenium. Most of these texts are charcterised by a focus on sw-architetures and the design-texts focus on cognitive benefits of movement in a WIMP context as also described by Bødker (2015). But research like Thomas and Calder (2001) starts to include the experience dimension in evaluations. Research within the third wave are clustered around Eikenes (2010) and his supervisor Andrew Morrison (Skjulstad & Morrison, 2005; Eikenes & Morrison, 2010). Their research is very much in line with the personal and affective approach to, and "multiplicity" of computing, that Bødker (2006, 2015) predicts and describes:

> The challenge in the third wave is exactly to encompass multiple mediators, and in particular other than PC-based ones. … While these mediators all consist of physical as well as logical elements, it is not the border between the physical and the logical as such that is interesting, it is as much the action possibilities or affordances offered by a certain configuration for a certain purpose (Bødker, 2006, p.3).

An analysis of Skjulstad and Morrison (2005), Eikenes (2010a), Eikenes and Morrison (2010) and the study reported in Part II show, how the multiplicity described by Bødker, at the interface level is expressed and concretely performed by the usage of movement in the design of interaction, and in particular touch interaction. Eikenes, Morrison and Skjulstad describes an ecosystem of constructed symolism – an environment to navigate with our mind via interpretation of these symbols. The ecological psychology describe a natural environment of matters and substances that we must navigate and interpretate with our bodies (Gibson, 1976). The interface fuses these worlds in a construction that draws on the users knowledge of both the symbolic and the physical environment from which the interface draws its references. From the study reported in Part II, where respondents agreed to movement as instilling meaning, and the definition of movement as bringing to life (section 17), then motion is the component that fluently integrates the two environments (symbolic and physical) as the transformational and transportational nature of motion allow boundaries between symbolic environments to be crossed while remaining at the physical level, which give this transformation and transportation a perceptually convincing incarnation. Animation allow the designer to fluently shape these transformations and transportations. When it appears as if motion is the design component that really makes touch interaction work then it is because touch interaction has moved away from the mouse-keyboard proxy and the WIMP paradigm. As reported in Part II, then people like to user their bodies (fingers) for direct information manipulation. No more simulation, but the creation of interfaces that truely shape information and gives it form, relations and behaviour in its own right – which is in line with the continuum of functional animation (section 17). Touch UI's with the content as interface are environments to explore and to directly manipulate. Touch interfaces are a new reality of information where information is given form and direct tangibility via negotiation of the boundaries between symbolic systems and perceptual stimuli. These understandings and the derived aeshetic has then informed new incarnations of the WIMP paradigm (Figure 38) which now decide how the human intellect is augmented – to paraphrase Douglas Engelbart.

This connects to the latter set of publications in the literature review and thus also the most recent research and reflections on movement as an interaction design component. These publications are originated in practice and focus on web, mobile, touch, content as interface and interfaces that adapt (responsive design (Marchotte, 2011)). The unifying approach to this evolution of the GUI, in parallel to the WIMP paradigm, is the paradigm of Natural user interfaces (Wigor & Wixon, 2011) or Reality-based Interaction as described by Jacob, Girouard, Hirshfield, Horn, Shaer, Solovey and Zigelbaum (2008).

Third wave HCI is therefore also the appearance of commercially viable alternatives to the WIMP GUI. The NUI pradigm represents such a paradigm. In the understandig of Wigor and Wixon (2011), then Natural User Interfaces (NUIs), must have emphasis on *natural user*, and less on interface. This is in line with the critique of Donald Norman (2010) who point out that "natural" does not exist as all interfaces are constructions and contextual and that behaviours are within these systesm are acquired, not "natural" or intuitive. Wigor and Wixon (2011) describe Natural User Interfaces as "… leveraging the potential of modern technologies to better mirror human capabilities". (Wigor & Wixon 2011, p.10).

The general understanding of human perception and cognition has evolved from an information processing paradigm, towards an ecological and embodied paradigm (Dourish, 2004). This is illustrted by Jacob et al. (2008) who propose four themes for what they call Reality based interaction as they refer to "… aspects of the physical, non-digital world" that huamns relate to Jacob, Girouard, Hirshfield, Horn, Shaer, Solovey & Zigelbaum (2008, p. 2): *Naïve Physics* which is the informal/common sense knowledge of the physical world possessed. *Body Awareness & Skills* which is the knowledge of and ability to control the body. *Environment Awareness & Skills* which is the ability to navigate and manipulate the surroundings. *Social Awareness & Skills* which is the ability to an knowledge about being with other people. The themes makes the understanings of Gibson (1979) more concrete as these are the cognitive skills and bodily awarenesses available for understanding and motoring about in the pysical world, but also the constructed digital world. Which makes this framework very illustrative of what is the material of the NUI paradigm: Human unconscious behaviour. The themes are illustrated by Figure 54

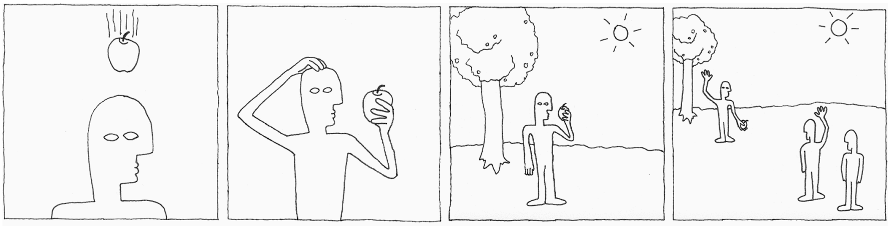


Figure 54. The 4 themes of the Reality-Based Interaction framework (Jacob et al., 2008).

The Reality-based interaction themes are a breakdown of the types of knowledge that a user posses when confronted with an interactive digital system. The natural interaction occurs if the system is based on supporting these skills and awarenesses. Meaning that the users physical, perceptive and cognitive capabilites are in focus for the interaction desgn. From the central role of movement in human existence extablished in previous sections, then this also locates movement as a central component in the NUI paradigm.

However, in their description of the NUI paradigm, Wigor and Wixon (2011) never address the connection between designing for touch and the use of movement, but most of the design approaches involve some level of movement in the interface. Most notably are the fundamental design principles of Seamlessness and Super Real. Seamlessness is the effect discussed in connection to the Cognitive Coprocessor and Super Real is basically the ability of animation to metamorpose and thus make unnatural movement appear convincing to the users equipped with their ”Reality-based framework”. Wigor and Wixon (2011) describe the naturalness as a symbosis:

> The naturalness of the NUI begins with a symbiotic relationship between the actor and the acting system (the environment). This symbiosis is the starting point for design, the touchstone for evaluation, and the determinant of initial success. The NUI system reacts in such a way as to show the user the next step or foreshadow the final outcome (Wigor & Wixon, 2011, p.30).

This description is in line with the basic statement about functional animation presented by Baecker & Small (1990) - review the past, understand the present, and describe the future. This must then be seen in relation to a description of the (N)UI as an environment. Wigor and Wixon (2011) thus indirectly put the interaction designer in a position as creators of worlds.

The NUI paradigm is in particular concerned with touch based interaction. The principles for NUI incorporate a lot of movement, but this is not made explicit. The dynamic behaviors of user interface components within the NUI paradigm is dependent on the design of movement which in some ways bring the story back to Ivan Sutherland who also created a system that unknowlingly was dependent on movement.

This also brings the story back to the cave paintings where naturalness and access to a parallel world of spirits created magic images in a similar fashion as tablets and mobile phones shapes and provides access to the realm of information. But this time the technology allow more dynamic pictures that truely react and unfold upon interaction.

> *We live in a physical world whose properties we have come to know well through long familiarity. We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well-known shapes look from other angles, and how much force is required to push objects against friction. We lack corresponding familiarity with the forces on charged particles, forces in non-uniform fields, the effects of nonprojective geometric transformations, and high-inertia, low friction motion. A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland*
>
> Ivan Sutherland, 1965

18.4 Summary

The previous sections have addressed research question 3 and provided a history of animation that illustrates how animation has inspired the inclusion of movement into the user interface since the first wave of HCI. Animation as an understanding of movement and a framework for working with movement has been part of interaction design since the inception of the WIMP GUI.

The literature points to Ronald Baecker as the driving force within functional animation during the first wave of HCI; and animator Eric Martin as the professional animator that supervised this inclusion.

The cosncious inclusion of movement in the user interfaces has two dimensions: One is the functional, to support the usrs practical goal of interaction. The other is the experiential which provide users with a natural feel of the interaction. Both of these dimensions are based on the ability of animation to metamorphose and do so in believable way.

The shared history is a contribution to both animation practice and animation studies. This is an added chapter of interactive animation to the known story of linear animation.

The usage of animation in the context of interactive digital systems is also a novel use of animation as animation has previously only been used for “story-telling” in a broad sense. But the use of animation is also a novelty as animation has not before been integrated into a practical setting as component of making a tool work. This observation is new.

This historic account of the overlap between animation and interaction design has not answered specificly *what* functional animation conretely is: Is any type of movement in an interactive digital media functional animation? Stasko (1993) has the following answer:

> The discussion of what is animation in the user interface: A blinking cursor, a change in colour, a scroll bar, a pop-up dialogue, a pull down menu, a moving window … animation at its essence involves smoothly changing positions or attributes of objects so that a viewer can observe the relationship between time t and time $t + \Delta t$ (Stasko, 1993, p.82).

Stasko’s (1993) answer contains two levels: One is the concrete examples, the other is an explanation by purpose. This point toward the following section which will address the types, principles and concreteness of functional animation.

19 PRINCIPLES

Animation can explain whatever the mind of man can conceive
Walt Disney, Animator

This section address research question 4: *What are the design principles for functional animation?*

Principles are collections of recommendations for best practice in an abstract format that allow transfer and application of this best practice to different contexts. This section will present the principles of animation (section 19.1) and a condensed set of principles for functional animation (section 19.2). The principles of animation are presented to provide insight into how movement is designed and thus the basis for the principles developed particularly for functional animation.

The principles of animation represent the condensed body of knowledge within the practice of animation. They provide a practical unfolding of relevant considerations for obtaining the effects discussed in section 17. The skilled animator must master these principles to control his material: motion. The relation and implications of each principle towards interaction design is discussed for each principle and an example from the realm of interaction design is provided.

The principles of functional animation represent the recommendations for practical application of movement when designing interaction for digital systems. This section will present a condensed set of principles based on the many sets of principles present in the existing functional animation literature.

19.1 Principles of Animation

Walt Disney and the Disney Studios are usually attributed as those that invented and refined character animation (Wells, 1998, 2009). Animation before Disney used to be mechanical/abrupt and the action focused on slap-stick humour (Thomas & Johnston, 1984; Furniss, 1998; Wells 1998, 2009). But Disney's focus on creating expressive characters with personality changed this. Disney cared about complete characters, complex storytelling and when the studio started releasing feature length animated films they established animation as a serious media. The first film being "Snow White" released in 1937 (Wells, 1998, 2002).

Competition between the Fleischner studio and the Disney studio drove much of the development in animation technique and expressivness during the 1920'ies, 30'ies and into the early 40'ies. But the Fleischner studios had to close, and "In subsequent years, the Disney studio secured its position as a dominant force in the American and world markets through other strategic manoeuvres, combined with a commitment to artistic commitment" (Furniss 1998, p.24). It is this latter commitment that produced the 12 basic principles of animation[72].

This section introduces the constructive and practical understandings of movement that constitutes the basics for the craft of animation. These understandings are formalised into a set of principles that animators use for deconstructing and constructing movement to create animated objects. I present these principles for two reasons: 1) To the non-animator (e.g. the interaction designer) they provide an understanding of the complexity going into the construction of movement in an otherwise non-motile object; and 2) The principles serve as a supplement to other understandings of movement presented in this report – e.g. the qualities proposed by Maxine Sheets-Johnstone (2011).

The principles of animation are the analytical and constructive tools of the craftsman doing animation. They are a practical guide for creating movement. Understanding and knowing these principles will not make anyone an animator, but one will be properly prepared to enter into a dialogue with a professional animator. Two sets of principles are presented: The basic 12 principles of animation and an extended set of principles.

[72] An endavour which was catalysed by art-teacher Don Graham. His approach to drawing is published in the book "Composing Pictures", republished 2010 by Silman-James Press.

The 12 basic principles of animation are those that are usually introduced when looking into “how to do animation”. The 12 principles were formalised at the Disney Studios in California during the 1930'ies. Walt Disney and his staff of animators analysed and refined their knowledge and experience with animation through collegial critique and disseminated their learnings through regular in-house seminars. These activities led to an increased understanding of how the various subtleties of movement can be controlled and how they affect each other and the overall result. The understandings were condensed into the 12 principles of animation.

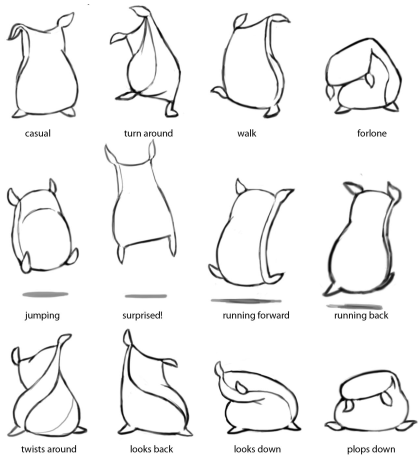


Figure 55. "The famous half-filled flour sack. A guide to maintaining volume in any animatable shape, and proof that attitudes can be achieved with the simplest of forms" (Thomas & Johnston, 1981, p. 49).

A lot of good descriptions and illustrations of the 12 principles of animation are available, both on-line[73] and in books. This description is based on animators Frank Thomas & Ollie Johnston’s 1984 book "The Illusion of Life - Disney Animation" (Thomas & Johnston, 1984) and animator John Lasseter’s 1996 SIGGraph paper "Principles of traditional animation applied to 3D computer animation" (Lasseter, 1996). These authors are recognised and competent animators and both texts are widely referenced in the animation and interface litterature.

Frank Thomas and Ollie Johnston were animators at the Disney Studios during the Golden Age of animation (1930-1970) and among the famous “9 old men” who participated in the process of analysing, refining and operationalising the understandings of animation formalised in the 12 principles (Furniss, 1998). Thomas and Johnston (1984) represent an original source for an introduction to the principles

[73] Example: vimeo.com/93206523 (accessed October 2016).

and how they got established. John Lasseter, was the animation capacity behind the establishment of Pixar. Pixar brought animation into the digital age like Disney Studios invented techniques and technologies for animation and got animation established as part of mainstream cinematic media.

John Lasseter and the team he was part of at Lucas film Computer Graphics Group and later Pixar believed that it was possible to create a fully digital, animated, feature length movie. They had the vision of proving the technical prowess of digital imaging technology while maintaining the artistic integrity that Lasseter had brought with him from his schooling at CalArts and the Disney studios. Pixar achieved this with "Toy Story" in 1995. In that process Lasseter wrote and presented the only academic paper of his career (Lasseter, 1996). The paper is respectful to the origins of the 12 principles and explain them well, while explaining relevance and usefulness in the context of digital 3D animation. The paper cement the value of the principles as they are not challenged or corrupted by the change of technological platform. An observation that also supports the relevance of the principles for animation within interactive animation and in particular functional animation.

19.1.1 Squash & Stretch

The principle of squash & stretch concerns deformation, or not. "By far the most important discovery was what we call Squash and Stretch" (Thomas & Johnston, 1984, p.47). When an object collides with another object, either of them at a standstill or both in motion upon impact, then deformation of either or both of the objects will signify something about the physical mass and responsiveness of the involved objects. When an object traverses a space without impacts, then the deformation of the object, will also signify something about the physical mass and responsiveness of the object, but also about the environment that the object traverses, and thus the relationship between the object and the environment. The experiential meaning of these effects were studied in the the study reported in Part II. Physical mass and responsiveness are both material properties, so the principle is central to communicating materiality of an object to the user/audience. In an interface context, then an object could be both an independent entity, like an icon, or a fixed entity, like a page boundary, or the invisible entity of space. The principle relates to considerations about where to locate a particular interactive object on the scale of mimicry for user interface animation (section 17.8).

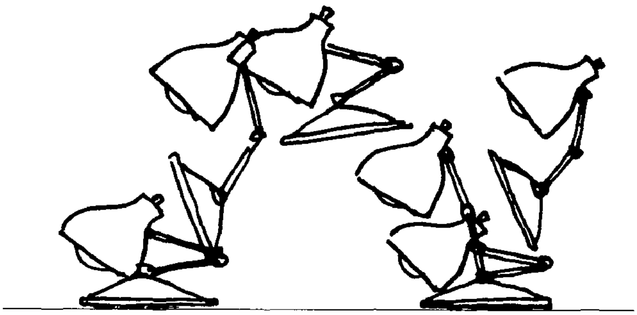


FIGURE 3. Squash & stretch in Luxo Jr.'s hop.

Figure 56. Squash & stretch as illustrated by Lasseter (1987).

The understanding of how to design material object properties resonates J.J.Gibsons description of the terrestrial environment as it lends itself to animal life: "… in terms of a medium, subtances, and the surfaces that separate them" (Gibson, 1979, p.12). Mediums are air (gas), water (liquid), and earth (solid). Each has different properties that establish conditions for animal life. A life that is dependant on adaptation of perceptive characteristics in the animal to understand and navigate the environment in which it lives. The perceptive system of different animals allow them to survive and utilise the affordances of the environment which by these perceptive characteristics establish a niche for survival: The medium, substances, surfaces, objects, places, and other animals offer affordances for a given animal. They offer benefit or injury, life or death. This is why they need to be perceived" (Gibson, 1979, p.134). Affordances is a much debated concept in interaction design and in particular Donald Noman has been critisised for his use of the concept, which he ultimately modified to "perceived affordances". I adhere to Gibsons definition: "Affordances are properties taken with reference to the observer. They are neither physical nor phenomenal" (Gibson, 1979, p.135). This means that something only has an affordance if the animal has the ability to perceive it. Walls are climbable to gekkos because their feet have properties to negotiate this vertical terrain, but mouse has different feet, good for grapping objects and digging tunnels. The wall is therefore not climbable to the mouse. It does not afford this action.

In connection to movement and interface design then affordances are relevant, because the designer creates environments in which the user will explore and navigate on order to "survive" – as in obtaining the goal of the activity[74]. The

[74] Life and death might actually be at stake. The history of interaction design contain examples from aviation on perilious events due to misinterpretation of sensory stimuli. The landinggear knob is by regulatory standard shaped like a wheel because WWII pilots mistook the flaps and landinggear handles, and thus pulled up the landinggear during landing. Much of J.J.Gibsons reseach was funded by the US Airforce.

concept of affordances is important in pointing to the necessity of a user interface to offer perceptible environmental characeristics to the human user. Designers must understand the particularities constituting the environment they have to design. Designers create artificial environments based on an understanding of the particular user, the particular context of use, and the task to complete via the interface (section 11.3). Particular interaction technologies, e.g. touchscreens, constitute a mediating factor between the user and the environment to negotiate. The issue then becomes how well the interaction technology mediates between human perception and the interface environment. In the case of touchscreens, then the screen is both medium, substance and surface in the gibsonian sense. Brett Victor refer to these devices as "pictures under glass" (Victor, 2006) and thus underlines the presence of a surface that separates one substance from another. The substances mimicked for representing information and the substance and medium within which the user moves his body and fingers for interacting with the content. The substance of the content must thus match the motile expectations of the user when gesturing within the gassy medium of atmospheric air. Gibson point to one of the roles of visual perception: "The substances of the environment need to be distinguished. A powerful way of doing so is by seeing their surfaces" (Gibson, 1979, p.27). The animal must explore the environment and seeing the surfaces is a way to do this. This is relevant in the context of touchscreen interaction as the screen is a hard medium: Glass. The substances (re-)presented in/by/on/at the screen only have a surface through their graphic appearance. This of course is possible due to semantic reference by the 2D graphics, and experience on the side of the user, in intepretating these (re-)presentations. But is is also possible because these "pictures under glass" are not static. They move and are susceptible to direct bodily originated manipulation, and they respond to this by moving. This means that even if the object does not look like anything known from physical reality, then the human user could perceive the reaction as a natural response to a their physical action.

Designers of touchscreen interaction create the basis for impression, recognition and accept, in users, of different substances (on the scale of mimicry). To do this they manipulate both the visual appearance and the motile qualities of the object. These were the parameters adjusted in the exercise in Part II to create a focus on movement and allow research of this particular phenomenon in isolation. Gibson views motion as an active proces and activity requires motion; for a digital interface to afford natural perception, then motion must be part of it, and motile qualities must be designed into the objects of the interface.

The squash & stretch properties of an object in an animated interactive environment will reflect the substance(s), its surface(s), and the medium(s) within which it exists.

Most of the remaining principles of animation serve to adjust details of the motile behaviour of the object, so that this behaviour elicit the intended impression and reaction from the user/audience. Squash & stretch is the core principle that turns an object into a material with certain characteristics. Squash & stretch is therefore also at the core of bringing alive and metamorphosing non-motile imagined objects into believable entities.

Squash & stretch is seen in touchscreen interaction when the top or bottom of a list is reached, then the items in the list will squash together when the user tries to pull the list further (iOS). This squash indicates a materiality of the entire list, as a unity, and tell the user that the pull action now has no effect because the list has reached the end state. Some lists use stretch to indicate similar state by pulling the list entries further apart giving the list an elastic materiality (Android).

19.1.2 Anticipation

Anticipation is a preparatory movement made by the object before commencing the main-action. It could be a slight backward movement to indicate the forward moving action to follow. Thus the action will also direct attention to the main-action. It is action before action and thus important in terms of pointing to what will be. ”Describing a future” in the sense of Baecker and Small (1990).

Anticipatory movement will use squash & stretch, as it is a movement of the object itself, or parts of it.

In user interfaces anticpation could indicate if object is to move position, or change appearance based on a system or user event. An example could be the slight movement upon touch, in an e-reader, of the page corner edges. This would indicate the possibility of paging. Paging being the main action, and the slight movement a preparatory action for the actual paging.

19.1.3 Staging

Staging the action is about steering, or directing the audience attention to the desired elements and actions, so that “its meaning, however, is very precise: it is the presentation of any idea so that it is completely and unmistakeably clear” (Thomas & Johnston, 1984, p.53). Staging is not only about the animated object, but also about how the environment presents and directs attention towards the important elements. Movement can be used for staging to direct attention to the intention of the overall action.

An example could be the transitions seen in many touchscreens when moving from one state to the next. The gradual “swing” of the tiles in a Windows Phone interface (ver. 8) stages the swinging action (=moving out of sight) by clearly showing where the tiles disappear to, thus providing a mental model of the information architecture.

19.1.4 Straight Ahead Action & Pose to Pose

Straight ahead action & pose to pose are strictly speaking not principles of animation if understood as actual movement. Straight ahead action & pose to pose are principles of animation production and refer to two different techniques for drawing the sequence of drawings constituting an animated scene. Either technique affects the character of the resulting animation/scene.

Straight ahead action creates dynamic movement as the technique requires the animator to create each frame in immediate order. In opposition to this is pose to pose which allow the animator to create socalled keyframes, which are significant ”middel-points”, or poses, in the movement being created. Pose to pose allow the animator to consider how the object behaves while moving from one pose to the next, while straight ahead action require the animator to draw sequentially from first to last frame without considering keyframes. Straight ahead action allow for spontaneity while pose to pose allow for clarity and strength (Thomas & Johnston, 1984).

The principle of Straight ahead action & pose to pose is not immediately applicable to the movements in user interfaces, or computer animation in general. Neither would this appraoch be particularly useful for e.g. clay animation. Lasseter (1987) also relegates this principle to handdrawn animation and proposes “… a much better approach in the context of a hierarchical modelling system, which works "layer by layer" down the hierarchy” (Lasseter, 1987, p.40) for computer animation. Chang and Ungar (1993) does not eiher include the principles when they applied cartoon animation to the Self user interface. But as approaches to creating and exploring movements in objects, then the principle is useful when sketching for functional or other types of animation.

19.1.5 Follow Through & Overlapping Action

Follow through & overlapping action are movements at the end of an objects main-movement. Like anticipation opens up an action, then follow through & overlapping action brings closure to the action by the movement of individual appendages of the object (if any). This allow for added expressivness of the main action as the follow through and overlapping actions may signify the nature of the action just completed.

Compared to Thomas and Johnston (1984), then Lasseter (1987) distinguish between the two actions: Follow through address the parts of an object which will continue to move after the main body of the object has halted. If the whole object just stops, then it will appear abrupt and rigid. The principle, like anticipation utilises squash & stretch to manipulate parts of the object. The purpose is to underline the solidity and expressiveness of the object as a whole. When the “moving hold” position is reached, then parts will continue to move to underline the end-position and desired expressiveness. Thomas and Johnston (1984) describe how the discovery of follow through & overlapping action improved their animation skills: “Now we could use the follow through on the fleshy parts to give us the solidity and dimension, we could drag the parts to give the added feeling of weight and reality, and we could strengthen our poses for more vitality. It all added up to more life in the scene. The magic was beginning to appear” (Thomas & Johnston, 1984, p .62).

The magic in touch screen user interfaces created via follow through & overlapping action is observed in the afore mentioned staging of appearance and disapearance of the main menu tiles in the Windows Phone interface. The tiles are at the same time a single unit, but also individual tiles. Within the movement of the tiles-unit, the individual tiles also move at individual paces, but maintain relation to one another as the unit they are. Each tile is performing an individual “swing”, which is also the swing of the entire unit.

In Lasseters understanding, then overlapping action is also a follow through action, that bring the object into a pose, but very possibly, then this pose leads to another movement out of the pose, meaning that the object moves on. The overlapping type of follow through is therefore a reminiscent of the previous main action that is still in effect, and thus overlaps when the next main action is commenced. Lasseter (1987) emphasize the importance of these overlaps to maintain flow and continuity in the action. Explained this way then overlapping action is very much in line with Baecker and Smalls (1990) description of how animation relates to past, present and future. Lasseter illustrates the principle by a quote of Walt Disney taken from an unpublished script by Disney Studios artist in residence Don Graham:

> It is not necessary for an animator to take a character to one point, complete that action completely, and then turn to the following action as if he had never given it a thought until after completing the first action. When a character knows what his is going to do he doesn't have to stop before each individual action and think to do it. He has it planned in advance in his mind. For example, the mind thinks, "I'll close the door - lock it - then I'm going to undress and go to bed." Well, you walk over to the door - before the walk is finished you're reaching for the door - before the door is closed you reach for the key - before the door is locked you're turning away - while you're walking away you undo your tie - and before you reach the bureau you have your tie off. In other words, before you know it you're undressed - and you've done it in one thought, "I'm going to bed (Lasseter, 1987, p.40).

This description examplifies how the principles of animation have implictions beyond the creative and express a deeper understanding of movment. The principles are the condensed set of movement breakown for buildup described by Cholodenko (2000) and referred to by Mclaren as “the anatomy of motion” (calibrations). The principles allow the animator to create sequences that make believable the characters, their actions, their location in the environment and their relation to this environment. The description by Walt Disney is also a description of embodiment and embodied interaction as defined by Paul Dourish: “Embodiment is the property of our engagement with the world that allow us to make it meaningful. … Embodied interaction is the creation, manipulation, and sharing of meaning through interaction with artifacts” (Dourish, 2004, p.126). This overlap in understanding of human relation to the world between Walt Disney the animator and Paul Dourish the interaction designer illustrates the complementarity between these fields of both practice and theory. Either field is defined by its relation to reality. By his description Walt Disney reveals how animation has come to master a significant part of reality. Both he and Paul Dourish are supported by Maxine Sheets-Johntone:

"Movement is a - if not - the constituting component of embodiment and knowledge of the world … we are not embodied minds but mindful bodies" (Sheets-Johntone, 2011). Maxine Sheets-Johnstone advocates how movement is at the core of establishing the meaningfulness referred to by Paul Dourish and she points to how the body is in the world before the mind. The mind is in the world qua and via the body. Gibson (1979) present a similar line of thinking by his accounts of perception as a activity established by the subjects motile engagement with the world. Motion, is in the view of Gibson, a fundamental prerequisite for (visual) perception, and thus meaningmaking in the natural environments. Dourish, Gibson and Sheets-Johnstone agree and their understanding of the relationship between meaning, existence and movement is also inherent in the animators understanding of how movement constitutes and creates meaning in even the most basic goals in the world – like going to bed or making a phonecall while walking the street or moving five circles to an X (section 11.3).

19.1.6 Slow In & Slow Out

Thomas and Johnston (1984) describe how the principle of slow in & slow out actually made animated sequences more mechanical. The principle regards the close spacing of in-between drawings around key frames to enable focus on that particular pose, but only very few frames in the "space" between these keyframes. This means that the object would be "zipping" in and out of poses and thereby creating a very abrupt result because the closeness of drawings affect the speed of the movement. Very few drawings between one keyframe position to the next creates fast movement. Many drawing slows down the movement.

The principle however, does inform the animator about the acceleration and decelleration of a moving object, and how the timing of individual frames affect the overall expressivity. "… it was still an important discovery that became the basis of later refinements in timing and staging … Walt continued to ask us to analyze the actions more carefully, and to understand how the body worked, since that was the only way to get the caricature of realism he wanted" (p.62). The important element in this comment about realism is how the Disney animators not only concentrated upon the movements of the objects, of the object qualities, or characteristicas – as in squash and stretch and related principles; but also about movement in space, movement of position. This means that from these principles we find 1) directions on how to imbue motile qualites into an object, but also 2) about how this object moves in space, from location to location. These aspects are in line with Sheets-Johnstones four qualities of spatiality and temporality.

19.1.7 Arcs

Like anticipation, follow through & overlapping action add motile detail and credibility to the material appearance of an object, then the principle of arches add detail and credibility to the movement between positions. The principle address "movement of" as discussed in Part II and spatial movement (Sheets-Johnstone, 2011). The principle call attention to how natural movements from one position to another rarely happens via a straight line, but usually describes curved path. Not adhering to this principle will make the movement appear mechanical and abrupt. This, of course, could be, the desired effect.

Arches should also be considered for movement of the appendages of the main object-body. Meaning that the movements described by follow through & overlapping action, and secondary action must also be considered as curved.

The principle applies to both horisontal and vertical movements. An object falling in a straight line will rotate. The application of arches to this “drop-line” will affect the experience of speed as straight arched objects are perceived as fast moving and strongly curved arches are perceived as slow moving. But no rule without exception (Lasseter, 1987).

Referring to a non-arching path of movement as mechanical is a metaphor also used by Thomas and Johnston (1984). Interactive digital devices are actually machines, and mecahnical movement would therefore seem appropriate. A discussion as to which motile metaphor would be the most suitable for digital aesthetics relates to the discussion of establishing principles and/ or motion gestalts for functional animation. Arches are part of many movements in mobile interfaces. The Windows Phone tiles transition use arches for the movement.

19.1.8 Secondary Action

A secondary action is an action that results directly from another action, a subsidiary action. It is a movement that supports and accentuates the primary movement. In a video interview on the making of “Finding Nemo”[75], one of the animators explain how Nemos father suddenly gained expressiveness when his eyebrows got involved in his mimics (yes, fish have got eyebrows in animated movies (and they talk, too)). The eyebrow movements are secondary actions supporting the overall expressivenss of the character.

It could be discussed whether not the eyebrows are actually the primary action. This is also noted by Thomas and Johnston (1984). The secondary action may even be the primary action and hold primary significance compared to the primary action, however the changes in a secondary action should always commence before or after the primary action, so that it will not go unnoticed and thus loose significance. “No action stands alone” is the guiding approach, which lies behind secondary action, but this also creates a complexity of actions, once follow throughs and overlapping actions are added. Thomas and Johnston (1984) describe this: “The chief difficulty lies in making a unified statement through the drawing and timing of separate, but related, parts”. This statement is interesting, not as much in acknowledgning a complexity also noted by Lasseter (1987), but by the terminology that illustrate how animation is a constructive activity operating by the same principles as other design disciplines. The 12 principles of animation represents the components that allow the

[75] Pixar Animation Studios, Walt Disney Pictures 2003

animator to create movement, and to do so in any object, in any context, and with any purpose, as also illustrated by the TPFD-model (Figure 28). The 12 principles are the breakdown of movement into a set of controllable and compatible parts (Stephenson, 1973). They make movement controllable and thereby give the animator government of the creative proces when designing movements.

In the context of interaction design then the fades and colourchanges when opening and closing menus could be seen as secondary actions. The iconic ”Slide to unlock” of Apple iOS has secondary action as the text fades when the slider is dragged towards the unlock-position.

19.1.9 Timing

Like squash and stretch is a basic principle that affect the impression of mass in an object, then timing is the principle that creates animation. It is the principle that makes two instances of the same object in slightly different poses come to life. Spining a thaumatrope is timing (Figure 45). The principle of timing concerns how many instances of an object, between two poses, to show within a specfic timeframe. The two poses at each end of the movement are keyframes and the frames inbetween are called, well, inbetweens. The five basic types of motion defined by McLaren all relate to timing (section 17.3).

Squash & stretch concerns shape and responsiveness and thus the impression of mass and material qualities. Responsiveness and reaction results from the timing of the squash & stretch movements. Timing is the basic principle that not only adds speed, but also, in cooperation with squash & stretch, weight, size, emotion and personality. This is in line with the spatial (squash & stretch) and tensional (timing) dimensions of Sheets-Johnstone. Timing creates meaning due to the control of those dimensions: “But the personalities that were developing were defined more by their movements than their appearance, and the vayring speed of those movements determined wheter the character was lethargic, excited, nervous, relaxed. Neither acting nor attitude could be portrayed without paying very close attention to timing” (Thomas & Johnston, 1984, p.64). The following is an example from Thomas and Johnston, that describe the effect of zero to ten inbetweens upon the experience of what action has caused the effect on a head turning to the side (Thomas & Johnston, 1984, p.65):

No Inbetween	THE CHARACTER has been hit by a tremendous force. His head is nearly snapped off.One inbetween … has been hit by a brick, rolling, pin, frying pan.
Two inbetweens	… has a nervous tic. A muscle spasm, an uncontrollable twitch.
Three inbetweens	… is dodging the brick, rolling, pin, frying pan.
Four inbetweens	… is giving a crisp order, “Get going!”, “Move it!”.

Five inbetweens	… is more friendly, “Over here”, “Come on – hurry up”.
Six inbetweens	… sees a good-looking girl, or the spors car he has always wanted.
Seven inbetweens	… tries to get a better look at something.
Eight inbetweens	… searches for the peanut butter on the kitchen shelf.
Nine inbetweens	… appraises, considering thoughtfully.
Ten inbetweens	… stretches a sore muscle.

This example is only relevant if the timeframe is the same, but the effect of timing is not dependent of technology. Timing is the same irrespectively of photographed frames or digital rendering.

I recommend acting out the above variations of head movement. But watch your neck when there are none or very few in betweens. An exercise that illustrates how much animation is also acting, and how much the meaning of the very same motional path changes only by altering the speed of the directional movement. It also becomes apparent why principles like squash and stretch, follow through, and secondary and overlapping action are important. It is simply not possbile to perform the variations without other bodyparts moving, either as a result of the energy in the primary movement (follow through), or by adding facial movements to underline the communicative intent of the movement (secondary action).

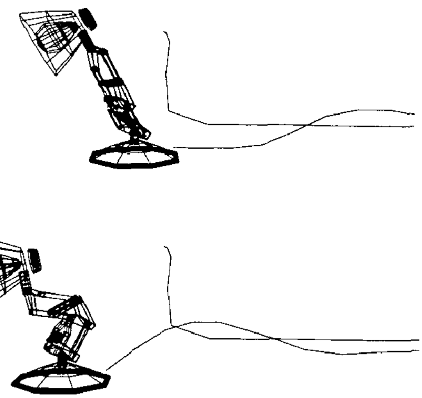
Interaction design is sometimes referred to as ”look n’ feel”. The looks are handled by graphic design (and a few more aspects), but the ”feel” must also originate from somewhere. Literally, then the feel for touchscreens is ”pictures under glass” and thus very smooth. But users do manage to get an impression of the materality or character of the objects they inteact with as the study in Part II showed. If timing is the principle that by the words of Thomas & Johnston, (1984) influence the impression of character and materiality, then timing could be seen to control the ”feel” of the digital environment.

Timing is also the principle that makes sure functional animation does not obstruct the users task completion by either not being dismisable, by occupying too much time, or by failing to execute within an acceptable timeframe. The latter actually being an issue related to sw and hw performance. Cao, Zieba, and Ellis (2015a) recommend animations to execute within 0.1 seconds to make users feel in control.

19.1.10 Exaggeration

Exaggeration has become a defining trait of animation and is probably responsible for the issues that have hampered the credibility of animation as a serious artform (Wells, 1998), as this principle is what constitutes the cartoonish character often associated and expected from animated products. This principle could be understood as a philosophy of how to obtain communicative effect. Thomas and Johnston

(1984) describe how Walt Disney asked for realism, but then did not approve the result "because it was not exaggerated enough" (Thomas & Johnston, 1984, p.65). But a colleague understood that "… he meant something that was more convincing, that made a bigger contact with people …" (Thomas & Johnston, 1984, p.66). Lasseter (1987) paraphrases Thomas and Johnston, (1984), when he explains the philosophical dimension of this principle: "The animator must go to the heart of anything or any idea and develop its essence, understanding the reason for it, so that the audience will also understand it" (Lasseter, 1987, p. 41). The keyword here is "essence". By exaggerating a select dimension of the object expressiveness, then the essence, the reason for a certain behaviour, will become clearer and the meaning of the behaviour will be clearly communicated. The animator therefore must be very aware of what it is he intend to communicate. Exaggeration seeks to eliminate ambiguity. The eyebrows of Nemos dad are exaggerated. Fish eyebrows ususally do not move that much (…), so the essence of his surprise or anger is accentuated by exaggerating the movement of the eyebrows. His surprise or anger, and how this affects the following actions is the essence of that particular piece of animation.



Figuer 57. Exaggeration as illustrated by Lasseter (1987).

Many of the other principles provide control of various dimensions of movement, but the principle of exaggeration suggests a special creative approach to convey artistic intent. Exaggeration is an artistic philosophy that uses the understanding of natural movement represented by the other principles of animation.

Exaggeration is in principle limitless, as long as the flow of movements have a recognisable, believable and consistent behaviour. Exaggeration is movement beyond the natural, to obtain some effect, but anchoraged in the natural. Wells (1998) speak of the charicature as a defining trait of animation. Charicature and exaggeration are both a kind of distortion. Exaggeration is the principle that incarnate the special relationship between animation and physical reality which by Small and Levinson (1989) was described as metamorphic.

Animation has the ability to manipulate what is known as natural motile behaviour, and push the believeability beyond physical reality, and maintain credibility in, and comprehension of, the object. This ability is in line with the Natural User Interface design principle “super realism” described by Wigor and Wixon (2011): “Super realism pushes beyond what is physically natural so that experiences do more than is possible in the real world. At the same time, super real is an intuitive extension of the real. Super[76] interactions are both grounded and magical” (Wigor & Wixon, 2011, p.47). This super realism is applied in many touch screen interaction patterns. Wigor and Wixon (2011) refer to how the size of a digital photograph can be manipulated and the scrolling behaviours of endless lists is also super real. Either example includes motion as the design component that makes the behaviour possible an believeable. Wigor and Wixon (2011) unknowingly describe how the super real behaviour pulls on the negotiation with reality embedded in eh principle of exaggeration. Super real is an exaggeration of the real thing. Super real is highly charicatured, distorted, exaggerated, and metamorphic, but yet believable. Animation negotiates human perception and experience with movements constitution of natural behaviour.

Lasseter (1987) provide a final comment on exaggeration: “A scene has many components to it: the design, the shape of the objects, the action, the emotion, the color, the sound. Exaggeration can work with any component, but not in isolation” (Lasseter, 1987, p.41). This statement underlines the understanding of exaggeration as an expressive philosophy as it only works in unison with other components. The statement also describe how an animated product is not only movement, but the result of integrating different types of expression. The completed animated product is a result of careful selection and manipulation of many different components.

19.1.11 Solid Drawing

Solid drawing is a basic principle of drawing: Form, weight, volume, solidity and illusion of 3 dimensions are obtained by this technique. As such then it is not a principle of animation, but rather and aesthetic favoured by the Disney Studios that allowed creation of highly expressive characters. The idea of creating an object that presents itself well for animation, should of course be considered for other contexts of animation. Lasseter (1987) only presents 11 principles as solid drawing is not included in his paper.

19.1.12 Appeal

The principle of appeal concerns the creation of objects that are believable. This is of course relative to where, what and why the object is placed in the action. In relation to functional animation, then an object could be have appeal in relation to how well is answers the eight questions of purpose suggested by Baecker and Small (1990).

[76] The word ”real” appear to be missing in the original text.

19.1.13 … more principles

John Lasseter (1987) concludes his paper by adding the principle of "Personality" as the overarching goal of the 12 principles. Norman McLaren provides 5 types of timing, but Walt Stanchfield presents 28 principles of animation (Stanchfield, 2009a, 2009b). These 28 principles overlap and extend the 12 principles presented by Thomas and Johnston (1984). Table 10 presents a comparative overview of Stanchfields principles and the basic 12 principles. This overview is not performed by an animator and only illustrate how animation principles extend beyond the basic 12 principles. These additional principles do not criticize the basic set, but add further aspects and nuances to the animators skillset.

The basic 12 principles	Principles by Walt Stanchfield
Appeal	Pose & Mood
	Shape & Form
	Anatomy
	Model or Character
	Weight
	Line & Silhouette
Slow In and Slow Out	Action & Reaction
	Perspective
	Direction
	Tension
	Planes
Solid Drawing	Solidity
Arcs	Arcs
Squash & stretch	Squash & Stretch
	Beat & Rhythm
	Depth & Volume
Follow Through and Overlapping Action	Overlap & Follow Thrugh
Timing	Timing
Straight Ahead Action and Pose to Pose	Working from Extreme to Extreme
	Straights & Curves
Secondary Action	Primary & Secondary Action
Staging	Staging & Composition
Anticipation	Anticipation
Exaggeration	Caricature

	Details
	Texture
	Simplification
	Positive & Negative Shapes

Table 10. Comparative overview of principles of animation.

Walt Stanchfield was animator at the Disney studios and during the 1970'ies he hosted weekly session at the Disney Studios which among other animators were attended by John Lasseter. Stanchfields association to the Disney studio, which also employed Frank Thomas and Ollie Johnston who described the 12 basic principles gives the principles of Stanchfield extra importance of as they have grown from the same creative environment as the 12 principles. Stanchfields principles have been as important as the 12 principles in shaping some of historys most successful animated products. This extended set of principles were brought to my attention during a conversation with lecturers at the TAW school of animation who were adamant to make me aware that animation is more than the 12 basic principles. The Walt Stanchfield sessions were collected in two volumes published in 2009 (Stanchfield, 2009a, 2009b). Walt Stanchfield has the following comment about the set of principles he introduces: “Here is a list of things (principles) that appear in these drawings, most of which should appear in all scenes, for they comprise the basis for full animation” (Stanchfield, 2009a, p.5). The drawing referenced by Stanchfield is reproduced in Figure 58.

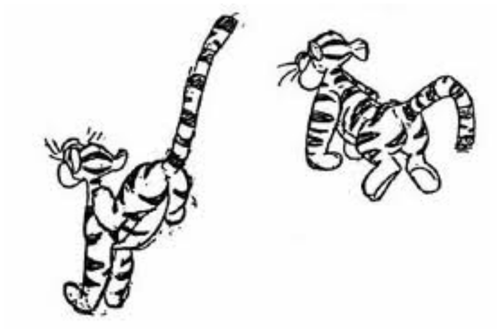


Figure 58. Tigger from Winnie the Pooh. Drawing from Stanchfield (2009a).

As it is apparent from the overview in Table 10, then there is absolute overlap to the classic 12 principles which is thus extended from 12 to 28. The literature on functional animation does, without exception, refer to the 12 principles presented by Thomas and Johnston (1984). The functional animation publications does not give the impression that many professional animators have been involved in neither research nor practical design of movement in the user interface. This is in itself critical and the presence of 28 principles underlines that the design of movement in interaction design could benefit from the involvement of professional animators.

Considering the widespread use of animation in touch devices, then this apparent absence, in particular within scientific research, is critical.

This extended set of principles indicate a potential for further research within functional animation and it implies that research based on the basic set of principles, could be revisited with these additional principles in mind and in assistance of a professional animator. The introduction of an extended set of principles is a novelty in the context of Interaction design and a contribution to the establishment of functional animation.

19.1.14 Summary

The definition of animation (section 17) analysed the abstract essence of animation. This section has provided insight into how animation concretely deconstructs and (re-)constructs movement. The principles of animation separate movement into controllable components by understanding the various parts, and their interrelations, whereby the animator gets control of the expressiveness that create the wholeness of a movement in and of a motile object.

The animation principles reflect the skillset that must be mastered by an animator. Adding to this is only his imagination and the aspect of material mastery. By this is meant the ability to manipulate e.g. pen and paper (or a digitizer) to create objects to animate. This material mastery is addressed by principles *straight ahead action & pose to pose* and *solid drawing* which are both reminiscent of animations origin in pen, paper and film cells. Different material skills exend the animators expressive reach and different materials possibly present different principles than those required for pen and paper. One such, for digital animation, was proposed by Lasseter (1987) in section 19.1.4.

The section has also discussed various aspcts of how animation relates to reality and it is apparent that the understandings of motile dynamics and meaning encapsulated in the principles of animation are similar to those of embodied phenomenology, ecological psychology, and not least interaction design. Movement and thus functional animation is an important element in creating interactivity.

The breakdown not only enable construction of movement, but also integration with other types of expression as these principles provide a language for how which effects are intended. This was briefly touched upon in relation to exaggeration (section 19.1.10). The principles therefore also lay the ground for a structured integration into a semantic and aesthetic complex like interaction design.

The 12 principles resemble the four basic qualities proposed by Sheets- Johnstone (2011) and in Part II, section 11.1.1.4 the two types of interactive movement *movement of* and *inert movement* were introduced. This indicate a possible grouping of the animation principles. A grouping makes the principles more transparent and available to non-animators. Within the functional animation literature Thomas (1998) propose the categories listed in Table 11[77].

MECHANICS	EFFECTS	STAGING & DIRECTING
Timing	Anticipation	Staging
Straight ahead action & Pose to pose	Squash & Stretch	Appeal
	Motion blur	Motivation
	Exaggeration	
	Slow in & Slow out	
	Arcs	
	Seconday action	
	Follow through and Overlapping action	

Table 11. Categories of animation principles by Thomas (1998).

The categories of Thomas (1998) are based on the idea of frame-based and linear animation. This is apparent from the placement of keyframe technique within the *mechanics* category. But the idea of separating timing into a particular category is in line with McLarens understanding of timing as the most important principle, as this controls the movement progression. The *mechanics* category therefore seems reasonable. Likewise does the *effects* category which basically includes every other principle that address some aspect of the actual movement. The principle *motion blur* has been added. The last category, *staging and directing*, has had the principle *motivation* added. This category address how the animated piece is presenting the individual components. *Solid drawing* is not included.

Bruce Thomas apparently continued his PhD work and therefore Thomas and Calder (2001) present a different categorisation of the 12 animation principles which specifically address functional animation, and thus interactive animation. This lead to the following section where the principles of functional animation are presented.

[77] Thomas (1998) refer to the following as inspiration: Karp, Peter; and Feiner, Steven (1990). *Issues in the automated generation of animated presentations*. In Proceedings of Graphic Interface 1990, Halifax, Canada.

19.2 Principles of Functional animation

The history of functional animation illustrated how the establishment of principles for functional animation has been the result of several research efforts. This purpose of this is to establish a proposal for a unified and condensed set of functional animation principles that will assist interaction designers and animators in their practical work.

The foundation for this set of principles is an understanding of what a principle is and how principles relate to other guiding components within interaction design. Cooper, Reimann & Cronin (2014) define princples as follows:

> Interaction design principles are generally applicable guidelines that address issues of behavior, form, and content. … Principles are applied throughout the design process, helping us to translate tasks and requirements that arise from scenarios into formalized structures and behaviors in the interface (Cooper, Reimann & Cronin, 2014. p. 173)

This explanation locate principles as relatively abstract, but yet oriented agianst establishing a concrete incarnation of the design object. To get more specific, then Cooper et al (2014) propose a beakdown of the design product from the concrete end of the design product. Figure 59 illustrates a hierarchical breakdown of a design product into the smallest possible components. For each component there exist an aspect of input and an aspect of output. The component may be a unit that allow either input or output, or both. The smallest possible components are *primitives*. Primitives are the smallest possible units of a product and represent the most basic types of actions (input) and reactions (output). Primitives are the only units that are not created from the combination of two or more other units. All other components are composites of other components. A composite element is created from units from lower levels or units at the same level as the composite itself. The composite elements represent complexities of functionality. The higher the level, the more complexity. Every constellation is unique. *Compunds* are the lowest level of composite components. A compound is created from constellations of primitives and allow basic functionalities. The last level of concrete components in Cooper et al. (2014) is *idioms*. Idioms are complexes of functionality that enable advanced actions and system functionality.

	INPUT	COMPONENT	OUTPUT
GROWING <------> NONE COMPLEXITY OF COMPONENT (number of elements)	e.g. delete, create, draw, etc.	IDIOMS Contextual commands and feedback	e.g. scrolling, sorting, dialogs, etc.
	e.g. double-click, button-click, selection, etc.	COMPOUNDS Composite actions and elements	e.g. edit field, checkbox, highlight, etc.
	e.g. point, press, touch, drag, flick, etc.	PRIMITIVES Unique and axiomatic mechanisms	e.g. cusor, text, etc.

Figure 59. Hierarchy of interface components adapted from Cooper, Reimann and Cronin,(2014, p.311).

These three levels of concrete components are used by the interction designer so embue the interface with interactivity. As the exmples in Figure 59 illustrate, then movement is part of most actions and reactions. The purpose of this hierarchy is to enable reuse of components. Reuse secures interface consistency and allow fast redesigns. Consistency is important for system usability and user experience. Consistency is a principle of interaction design.

The next question is how the principles connect to the idioms, compounds and primitives. The concrete low level components should, in the design prodcuct be the manifestations of the principles applied to the design. What is the relation between principles and idioms? In the above description of principles by Cooper et al. (2014) they refer to principles as guidelines. This is not consistent with Ritter, Baxter and Churchill (2014) who distinguish between *Standards*, *Principles* and *Guidelines*. The complexity of “how to design pointers” increase as Tidwell (2010) address the issue of guiding interaction design from the perspective of *patterns*. Patterns are also introduced by Cooper et al (2014). Based on the many different types and levels of design advise it is possible to construct the hierarchy of interaction design components introduced by Figure 60. A thorough account of this model is a research project in its own and the model is therefore a preliminary proposal for the purpose of discussing functional animation principles.

<table>
<tr><th>COMPONENT</th><td rowspan="9">ABSTRACT ← ... scale ... → CONCRETE</td></tr>
<tr><td>VALUES
Overall approaches to the design effort that informs all design decisions</td></tr>
<tr><td>STANDARDS
Do's and don'ts that should not be violated as they frame the design solution</td></tr>
<tr><td>PRINCIPLES (heuristics)
Design rules based on human psychology: Perception, Learning, Reasoning, Memory & Recall, Conversion of intentions into actions</td></tr>
<tr><td>GUIDELINES
Recommendations on best practice for specific or more general design issues</td></tr>
<tr><td>PATTERNS
Contextual complexes of commands and feedback</td></tr>
<tr><td>IDIOMS
Contextual commands and feedback</td></tr>
<tr><td>COMPOUNDS
Composite actions and elements</td></tr>
<tr><td>PRIMITIVES
Unique and axiomatic mechanisms</td></tr>
</table>

Figure 60. Hierarchy of interaction design components. The bold line indicate a threshold between abstract recommendations and concrete instantiations.

The model unifies the concrete components presented in Figure 59 with the abstract components that inform the concrete form. The model is sliced horisontally by a black line that indicate a threshold between the concrete and the abstract. In the concrete area the components have form in terms of colour, shape, sound, actions and of course motility. The concrete components have had the level *patterns* added. Patterns are contextual complexes of commands and feedback that address a specific functionality.

The abstract part of the hierarchy contain the components that inform the design decisions that will form the product specific incarnations of the concrete components. *Values* are very high level perspectives that must inform and lead all the design-decisions.

Google Inc. (n.d.) and Microsoft Inc. (n.d.) provide incarnations of the entire complex of components that describe how a particular product must look and behave. These documents are *Standards*.

Principles are design rules based on understandings of human psychology. This definition is based on Johnson (2010) and match Cooper et al. (2014) that refer to principles as "behaviour". But they also refer to principles as "guidelines … for form and content" and this is *Guidelines*.

Movement is not directly represented in the hierarchy of components, but the model allow mapping of the exiting principles, guidelines, etc. of functional animation.

19.2.1 Types

Bartram (1997) propose three types of movement within functional animation which are all related to their purpose: *Object-related motion*, *Observer-related motion* and *Deitic motion*. *Object related* motion will "communicate the meaning and content of the information objects and relation between them". *Observer-related motion* "… is concerned with the current user interface state and with manipulating the display configuration (viewpoint) to draw attention or at least perception to the desired area". *Deitic motion* provide an illustrative narrative (Bartram, 1997, p.1690).

Deitic motion is the the use of motion in the linear sense and without interaction. Object-related and Observer-related describe the particular ascpect of relatedness within interactive animation that was defined as autonomy in section 17.8. Within interactive animation the execution of the movement is dependent on some event. An event could be a users actions or a change system state. This relatedness was also observed in the exercise in Part II as it became apparent that the experience of the motile properties of the objects were dependent on the respondents actions. If the item was dragged slowly, then even the neutral pattern would be pleasant, whereas dragging the same item quickly would make i annoying. Adding to this is the influence of the environment which in the exercise were represented courses and then furthermore the purpose of the interaction – the task to perform. Movement within interactive animation and in particular functional animation therefore has this relatedness where the actual motion experienced by the user is relative to the quality of the event that triggered it. In the ecological sense, then the motile properties are true affordances because they are a result of the quality of the event that makes it "execute". Within this relatedness and autonomy is therefore also dependency between the motion as latent and the emergence of some action that will make the movement execute. The autonomy in interactive animation is dependent on a action-reaction relation. It is cause and effect. As Bartram states: "The *type* of motion pertains to its behaviour and *affordances*" (Bartram, 1997, p.1690). But as the experience of the motion is dependent on the quality of the input (the event), then the type and communicative quality will depend on how the input establish the relation – slow drag: nice object, fast drag: annoying object. The autonomy of interactive animation describes the same autonomy as is innate in objects in the world of atoms. Any object has innate motile qualities that will reveal themselves as a function of the quality of the input. The motile pattern of an object ranges from static to soluble.

Bertram's types fit this relational aspect of interactive animation, but are more descriptive and analytic than useful for creating interactive motile objects. Two types of movement, *innate movement* and *movement of*, were proposed in section section 11.1.1.4 and defined in relation to Sheets-Johnstones four basic qualities of movement (which appear to be inspired by Laban and Lawrence (1973)). These types should not be mistaken for principles. These are types of movement that grew out of the work with the exercise for the "meaning of movement study" in Part II. A such, then they are experience based, but also build on the understanding of movement expressed over the past pages. *Innate movement* and *movement of* represent the most basic and concrete types of functional animation, and probably movement in general. Combinations of *movement of* and *innate movement* produces a *motile pattern*. The motile pattern constitutes the potentiality of effects that the user will experience upon interaction. For the designer, then any element in the user interface should be considered from these two perspectives as this will provoke reflections over the motile qualities and element relations to the "eco-system". Movement of and innate movement could be described as follows:

Movement of	Can the object move from one location to another. - the effort and/or event required to make the object move
Innate movement	Does the object have the ability to change appearance over time. - the qualities of metamorphosis designed *into* the object.
Motile pattern	A combination of *movement of* and *innate movement* that constitues the motile affordances of the object - the collected motile behaviour and abilities

The Deitic motion type proposed by Bartram is basically the installation of linear animation within the interactive setting to support the system-to-user communication. This would be the types of functional animation that Baecker & Small (1990) refer to as *demonstration* and *explanation*. Thys type was explored in Baecker, Small and Mander (1991) as aniamted icons and implemented in the Apple Lisa as as the LisaGuide which was an introduction to system features embedded into the actual user interface as a feature avialble to the user Birss, 1984, p.323). This does not qualify as interactive or functional animation, but does illustrate that there is a grey zone between the interactive and the linear type of animation.

The definition of innate movement open a discussion of when a change in appearance qualifies as functional animation. For now, the proposal is, that any change is functional animation. Any quality of an object that affects it ability to not be static, either in location or by appearance qualifies as functional animation. Is the motility of the pointer functional animation? Yes, it is. The pointer exhibits movement of and in some systems the pointer will metamorphose appearance depending on location on the screen or as a result of an event. How then, about the change of colour on "a button" when the cursor moves over the object? Yes, this is also functional animation. The change of colour is a reaction to an event and a change in appearance over time. But it is of course, very poor animation.

19.2.2 Principles

Principles for functional animation are specifoc to the construction of motile patterns in support of the principles for interaction design. I shall refer to the principles of interaction design as system principles. The principles of functional animation support the mechanisms addressed by the system principles. A system principle like *feedback* (Johnson, 2010) is also addressed by functional animation via guidelines on how to construct motile patterns that within the system context will provide feedback (relevant to system status and events). In this perspective and as my use of the phrase "guideline" indicates, then functional animation principles reflections of system principles. Baecker & Small (1990) do not usee the phrase "principles" but just describe the eight different communicative capabilities. These capabilities could be viewed as high level purposes offered by functional animation to support system principles. The system principles *feedback* is adressed by Baecker and Small (1990) via most of their purposes, but from a different perspective – a different purpose: What type of feedback is required? This mechanism is due to the relational nature of interactive animation. The contextual purpose of the motile pattern therefore defines how this pattern should be designed. Principles of functional animation concern the purpose of the movement.

Baecker and Small (1990) describe eight purposes and Daliot (2015) describes nine "logical purposes". Daliot (2025) is a practice originated text. Baecker and Small (1990) refer to this role of animation within computer systems as "Functional" (see section 18.3.2) and the titel of Daliot (2015) is "Functional animation in UX design". This dissertation is meant to establish "functional animation". These purposes therefore constitute a central aspect in understanding the functional animation phenomenon and in operationalising functional animation. The following is an attempt at merging the purposes proposed by Baecker and Small (1990) and Daliot (2015). Daliot (2015) is an online text and include illustrations. The names of the suggested principles are a result of the merger.

19.2.2.1 Transition

Transition (Baecker & Small, 1990) is an orientation of the user from and about one process or system state to another. Daliot (2015) suggest the term *Orientation* and the logcal purpose as "Avoid a surprising transition, and orient the user". The example of Baecker and Small (1990) is that of a MacIntosh (1990) folder opening into a new window where the open action is illustated by a transition of a gradually growing window frame that positions the final window in relation to the original folder. The exact same illustration is used by Daliot (2015). Another important example is the many transitions between system states implemented in mobile devices where screen-content is folded, zoomed, tiled, etc. away and new screen-content is similarly brought into view. This type of transition illustrates space and communicates this space to the user and thereby the location of interface elements. It is movements that support a spatial mental model of information and system relations.

19.2.2.2 Transformation

This principle could be categorised as a special case of *transition*, but is described as a unique type as the purpose is not a change in state, but a change in appearance and functionality. Daliot (2015) propse the category Zoom In with the logical purpose to ”Associate a thumbnail with its detailed view”. This describes his examples, but the actual phenomenon is the central ability of animation to metamorphose, dissolve and negotiate the object form. This ability will in the interactive setting not only allow a change of shape or location, but also in functionality.

19.2.2.3 Progress

Feedback (Baecker & Small, 1990) is about informing about system status and processes. This is by Daliot (2015) refered to as *System status* and the logical purpose as “Impart a sense of control in a linear process”. Scaling, transparency, color and bar graphs are given as possible expressive formats for animated feedback mechanisms by (Baecker & Small, 1990). Daliot (2015) examplifies by a progress indictor for a download process. The category “Feedback” is based on research by Brad Myers (1984, 1985) into how icons of the Sapphire system can communicate process status and progress. I have chosen not to include these in this review as the contributions are represented by this text.

19.2.2.4 Acknowledgement

Choise (Baecker & Small, 1990) is to allow (e.g.) menus to be hidden away, but to get revealed via animation upon activating a single screen object. Again the example is taken from the MacIntosh menusystem. The possible benefits would be saving of screen real estate, avoidance of obscuring other screen objects, and allowing menu content to be dynamic as only what is relevant need to be displayed. Baecker and Small (1990) propose a set of motile patterns for these menu-revelations. Daliot (2015) propose the category *Visual feedback* with the logical purpose to ”Acknowledge the user’s action”. This latter description also cover the actions described by Baecker and Small (1990) and establish the very importnat purpose of functional animation of providing feedback upon a users action. Basically this is what ”physically” creates the *inter*-action as the object acknowledges the users action by reacting.

19.2.2.5 Hint

Demonstration (Baecker & Small, 1990) is aimed at improving the informative value of icons and other objects used to perform actions. This usage has some overlaps to that of “identification” (Baecker & Small, 1990), as the aim is to illustrate the functionality of something, but in the case of “demonstration” the targets for animation are the idioms (Cooper et al, 2014) (re)presenting system functionalities. The aim is to increase the amount of information and clarify the function available via this idiom. Baecker and Small (1990) end the description by stating that “.. research is required to determine the perceptual and cognitive implications of such animation” (Baecker and Small,1990, p.261). This is a clear pointer to the work undertaken later by Baecker, Small and Mander (1991) about animated icons and the example for *demonstration* also appears to be taken from this study as it is an animated MacIntosh Hypercard Erase icon. Daliot (2015) has two categories that appear similar and are covered by the notion of demonstration: *Visual Hint* with the logical purpose ”to exhibit unconventional functionality or a hidden action” and *Same Location, New Action* with the logical purpose to ”Emphasize a functional change in an action button”. Both descriptions share the aim of demonstrating a feature that would otherwise not be discovered.

19.2.2.6 Attention

Highlight is a category proposed by Daliot (2015) with the logical purpose to ”Grab the user’s attention, and rise above a noisy layout”. This should not be mistaken with *Hint* as the purpose is not to inform about a possbility, but to ask for attention. The description of Daliot (2015) does not entirely cover the potential cases as the call for attention is also useful in relation to critical system events. The principle build on the sensitivity to motion of human peripheral vision which makes it easy to catch the attention via movement even if the users sight is focused on something else (Johnson, 2010). Johnson refer to this use of motion as ”flash or wiggle briefly” (Johnson, 2010, p. 75) which also indicate that functional animation for attention is potentially annoying.

19.2.2.7 Illustration

Explanation (Baecker & Small, 1990) is aimed at using animation for explaining and teaching about the system features, and is explicitly inspired by the animated “Guided Tours” found in eg. the Apple LisaGuide and later gone horribly wrong with Microsofts Mr.Clippy concept. Daliot (2015) propose the category *Simulation* with the logical purpose to ”Simulate topics that are otherwise hard to convey”. The example used by Daliot (2015) is a brief illustration of what a ”goal menas within the game of football”. This illustration allow a fast explanation of something otherwise complicated and the animation performs as an integrated part of the interface. This is not interactive animation and as such not functional animation. But a relation of the animation to the functional context as suggested by Baecker and Small (1990) could allow linear pieces of animation to qualify as functional if they appear as integrated into the system functionality. This is a grey zone and *illustration* is per definition ”linear animation with the purpose of informing” as illustrated by the TPFD-model (Figure 28).

19.2.2.8 Non-functional principles

Illustration might be the exception, but some of the categories proposed by Baecker and Small (1990) and Daliot (2015) do not apply to an understanding of functional animation as a type of interactive animation:

Presentation

The category *Identification* suggested by (Baecker & Small, 1990) address animation at the beginning of a system session as a way of introducing the system, the system manufacturer or drawing attention to important features. This is not interactive animation, but linear animation applied to the functional void between activation of a program and the program being available. Daliot (2015) propose the category *Marketing Tool* with the logical purpose to ”Support a company’s brand values or highlight a product’s strengths”.

Error handling

The category *Guidance* suggested by (Baecker & Small, 1990) is not a purpose at the level of functional animation, but a system principles that might be supported by functional animation. The idea of Baecker and Small (1990) is that *Guidance* address the usefulness of errormessages and suggest that animation has the potential to make errormesages less intimidating, more informative and thus better guide towards faster solving of errors. Like “Identification”, “Demonstration” and “Explanation”, then the fundamental assumption is that animation will allow more, better and comprehensible information to be communicated (Baecker & Small, 1990, p. 267). This compares to system principles like “make users feel they are in control” and “help users recognize, diagnose, and recover from errors” (Johnson, 2010, p.xiii). This category is another purpose of the category *presentation*.

Backtrack

History (Baecker & Small, 1990) is a use of animation to enable playback a record of previous actions. This could be to guide if the user has become lost in the system, or to record a set of complex actions. This usage is rooted in systems with less usability than what has become the standard of today, but systems do exist that allow capture of workflows. The proliferation of cameras on mobile phones will have substituted the cases envisioned by Baecker and Small (1990).

The examples provided for the categories point a the establishment of collections of motile patterns or motile gestalts for these purposes. But this will not be addressed within this dissertation.

19.2.3 Guidelines

Thomas & Calder (2001) propose a set of principles for functional animation. These principles are not principles but guidelines. They build on much of the literature etsablshed at the time of publication and are explicitly offered as a refinement of the guidelines presented by Chang and Unger (1993). This set as presetned and tested by Thomas and Calder (2001) will presently represent state of the art within functional animation guidelines.

1. The principle of **attachment** states that the objects being manipulated should at all times remain attached to the pointer, which maintains the impression that the user is always in control of the action.

2. The principle of **reluctance** states that objects should, in general, seem reluctant to change, which reinforces the illusion of substance by suggesting that changing an object requires effort on the part of the user.

3. The principle of **smoothness** states that objects must change in a continuous fashion, which reduces cognitive load by removing large and unex- pected changes in visual information presented to the user.

4. The principle of **anticipation** states that the result of a user's action must be obvious at all times, which reduces cognitive load by supplying additional visual information and minimizing the use of short-term memory.

These guidelines are all developed for the WIMP GUI, but have not been tested for NUI interfaces. Different user interface paradigms will require different sets of guidelines and maybe also principles. This conflict is illustrated by Figure 61. Some principles and guidelines will probablyoverlap, but the concrete consequences in terms of motile patterns/ motion gestalts will be different.

	USER INTERFACE PARADIGM								
	GUI			**NUI - Touch**			**NUI - Kinestetic**		
GUIDELINE	Pattern X	Pattern Y	Pattern Z	Pattern X	Pattern Y	Pattern Z	Pattern X	Pattern Y	Pattern Z
Attachment									
Reluctance									
Smoothness									
Anticipation									

Figure 61. Model for applying functional animation principles in relation to design patterns.

19.2.4 Values

The model for design components (Figure 60) suggest the presence of values to guide a design. This research of functional animation, an in particular the context of touch screens has led me to propose the following values for functional animation:

Design for information — Information is the material of digital technology. Animation allow information to be dynamic, contextual and relational. Interactivity allow manipulation. The combination allow digital objects to come alive.

Design for Manipulation — Interface objects must inspire and facilitate interaction and provide meaningful feedback and feedforward. Objects are not entities, but relations to other objects.

Design for Exploration and Findability — Screens are units of information that constitute the larger system complex. The design should inspire and facilitate exploration of this complex.

19.3 Summary

This section addressed research question 4 and proposed a merged set of principles for functional animation and a set of guidelines based on existing research. These sets of principles and guidelines are proposals and not based on empirical evaluations.

The principles and guidelines are meant to operationalise the concept functional animation. The proposed principles are partly based on practice as one source is a practicing interaction designer.

20 FUNCTIONAL ANIMATION FRAMEWORK

There are unknown forces in nature; when we give ourselves wholly to her, without reserve, she lends them to us; she shows us these forms, which our watching eyes do not see, which our intelligence does not understand or suspect
Auguste Rodin, Sculptor

Movement is movement. Meaning: moving an object in a straight line from A to B is just that: moving an object in a straight line from A to B. But: How does one describe *moving in a straight line* so that others get the same understanding of this movement as envisioned by the designer. Some might imagine the object anticipating the movement and then accelerate gently, but coming to an abrupt halt with no follow through. Others might imagine no anticipation, but rigidity in the object (as it represents a lot of data) and then for the object to follow through upon reaching point B because it is so heavy.

Precise communication of design solutions is imperative within interaction design as system consistency is crucial to system usability and positive user experience. Consistency is obtained by applying similar behaviours to similar use cases within the system. This is secured by communicating unambiguously among those having responsability for the system design and implementation. To communicate movement it is necessary to have an agreed upon vocabulary. I refer to such a vocabulary as a framework.

This section address research question 5: *How could design principles manifest a framework for design, documentation and communication of movement in the design and development process?*

This research question address the practical requirements following the establishment of principles as the practitioner must be able to operationalise these principles. The question address both the design and the development process. The design process is part of the development process as illustrated by Buxton (2007). The design process could be described be as the initial stages of the development process. As illustrated by practitioners like Caddick and Cable (2011), then communication and documentation activites are as important within the development process as the actual design activities. The four styleguide documents included in the literature review examplify such communication and documentation efforts (Apple Inc., n.d.a; Apple Inc., n.d.b; Google Inc., n.d.; Microsoft Inc., n.d.). Mirlacher, Palanque and Bernhaupt (2012) is the only publication within the functional animation literature review that address these issues of supporting the design effort and the parallel and subsequent documentation and communication of the design decisions:

> While animations might increase usability, they also increase the complexity both for the specification and implementation of the software part of interactive systems, and therefore the probability of occurrence of faulty or undesired behaviors. For instance, the time-based nature of animations makes them hard to specify and hard to define and assess the detailed temporal behavior prior to implementation (Mirlacher, Palanque & Bernhaupt, 2012, p.111).

Mirlacher et al. (2012) propose a process that start with low fidelity prototyping that identify objects and states to animate. This is followed by high fidelity prototypes that identify various high level components like graphical aspects of an object, properties to animate and behaviour. The high level components of the high fidelity prototype are broken into atomic components which is a basically the manipulable numeric parameters. The aim is for the breakdown to "… bridge the gap between design/description and implementation" (Mirlacher et al. 2012, p.111). This lead to the proposal of a framework, or model which support this detailed breakdown of the movement, that enable communication of the design. The proposed framework appears reasonable, but also complicated. However, the framework does not take any principles of functional animation into account. For functional animation to have practical impact, then design and development tools must support the understandings of movement and animation represented by functional animation. A framework build around the functional animation principles will disseminate these principles to interaction design and animation practitioners and thus establish a dialogue around these and the theory they represent.

The framework presented via Figure 62 is a sketch: an open-ended proposal for how a framework could be established. A fusion with the framework of Mirlacher et al. (2012) could also be envisioned as they move into much more detail, both conceptually and in breakdown of movement. The goal is to establish a framework that build on and make the principles of functional animation available to interaction design and animation practice. The framework has not been tested.

		Pattern X								
		Idiom X			**Idiom Y**			**Idiom Z**		
Purpose	**Event**	Property X	Property Y	Property Z	Property X	Property Y	Property Z	Property X	Property Y	Property Z
Transition	Gesture X									
	Gesture Y									
	Gesture Z									
	Event X									
	Event Y									
	Event Z									
Trnasformation	Gesture X									
	…									
	Event X									
	…									
Progress	…									
	…									
Acknowledgement	…									
Hint	…									
Attention	…									
Illustration	…									

Figure 62. A framework for creating, documenting and communicating functional animation.

The framework combines the model for principles presented in section 19.2 and the general model for interaction design components presented in Figure 60.Figure 62 illustrate the framework. Currently there is no content in the matrix. It is a conceptual model of a potential tool. The horisontal axis, the rows, contain the event that may affect a motile reaction. These are filled in with the purposes defined for functional animation in section 19.2. The vertical axis, the columns contain the motile properties of the component in question which may react upon the event. Rows are cause and columns are effect. The mecanism in the framework is the relation between cause and effect, action and reaction.

As the principles section pointed out, then different interaction paradigms will require different sets of principles. The contents of the matrix should therefore reflect the context. The matrix layout provide flexibility in terms of content, but also in terms of scaleability as the components may be broken down into smaller entities in accordance to the hierarchy of components. The example in Figure 62 is at the level of idioms and allow the motile properties to be described in relation to certain events (gestures). The contents of the cell would be examples or parameters.

The framework could work 1) as a tool for categorising interface animations in a theoretical perspective 2) as a tool for reflection and sketching in a design setting and 3) as a tool for documentation and communication in a design process.

Depending on where in the designprocess the animator is working, the contents will be different. If early in the process, then the framework could inspire sketching activities and later in the process the contents could be specifications to be communicated to developers.

From a creative perspective, then the framework could be used as a checklist for the designer/animator to review the motile qualities of the pattern. This again could allow for better overview acoss different patterns and help secure consistency in the interface.

In a practical design setting then the framework might not look like this as the format is not practical. The cells are very small and cannot contain a lot of information. Neither does the format support visual communication very well. But the format is useful for to illustratin dependencies and relations among causes (events) and effects (motile pattern).

The framework operationalises work with movement in the user interface without compromising the creativity, but provides a structured and formal setup for handling a complex phenomenon. A setup which builds on established knowledge.

From a functional animation perspective, then the framework could help build and collect catalogues of motile solutions (motile patterns or motile gestalts). Within this catalogue some generic solutions might appear. This catalogue could evolve as usages, features, technologies, people and aesthetics change.

The framework point to the investigation that I initialy abandoned (Appendix C). The framework is the tool not available at that time and possibly the outcome that would have been useful for Noka and Bang & Olufsen. The framework constitutes a potential pattern library for functional animation (motile patterns or motile gestalts). Filling in the framework will challenge the principles, guidelines, etc. described in section 19.2. But the framework must then adapt if not able to contain novel aspects.

Harrison et al. (2011) present understandings of motion from a variety of areas as inspiration for designing the motile patterns used for their prototypes: Biological motion, Gestures, Organic motion, Mechanical Motion, Physics & Natural Effects and Cartoon conventions. The latter being the principles described in section 19.1.

Park and Lee (2010) and Park, Lee and Kim (2011) refer to the Laban Movement Analysis framework which is widely used within dance, acting, sports and optimisation of movement for manual labour (Laban and Lawrence, 1974). This framework is based on four main elements of movement: Weight, Shape, Time and Flow. Within these the *effort* perspective is given particular importance. Effort is constituted by respctively *exertion*, which is described along a scale of *light* and *strong*; and *control* which is described along a scale of *fluent* and *bound*. Laban's system grew out of dance and bears some resemplance to the four qualities of Sheets-Johnstone (2011). Like Sheets-Johnstone's four basic qualities then Labans framework might be less inspirational and better suited for analysis and description of movement.

20.1 Summary

A provisional framework for designing, communicating and documenting functional animation has been presented. The framework is not tested in practice and represent a first iteration. A framework is based on the principles of functional animation as these repesent a substantial body of research and knowledge about movement and animation. It is therefore important that a framwork of functional animation is based on these principles. The framework should enable creative control and inspire animators and interaction designers. The framework also enable dissemination and dialogue around functional animation.

21 CONCLUSION PART III

The previous sections have addressed research questions 1-5 via an investigation of Animation studies, Definition of animation, the History of animation, Principles of animation and functional animation and the proposal of a Framework for functional animation.

Part IV will conclude the dissertation via three sections: Discussion, Conclusion and Perspectives. The conclusion of Part III will therefore be integrated into the Conclusions section of Part IV as all section in Part III address a research question.

PART IV

WHERE ARE WE NOW: ARCHS, FOLLOW THROUGH & OVERLAPPING ACTION

Any sufficiently advanced technology is indistinguishable from magic.
Arthur C. Clarke, 1973

Any sufficiently advanced technology is indistinguishable from reality.
Morten Lund, 2016

22 DISCUSSION

This section address research question 7: *What are the implications of functional animation for interactive digital systems?*

The nature of the material of animation: movement, has been a persistent challenge within this project. Sheets-Johnstone (2011) establish movement as the foundation for life and illustrates how this phenomenon is present everywhere. Animation allow movement to be mimicked and the animation principles provide a breakdown of the phenomenon into creative components. Animation can be applied in a multitude of contexts, one of them being interactive digital systems (Figure 28). Working with movement is challenging because it metaphorically moves, changes shape and meaning. Establishing concepts and categories that make the phenomenon manageable is a challenge. Continuum definitions match the ephemeral phenomenon well. The relation to reality is another challenge, or more likely: the cause of the first challenge. Animation both mimics and challenges reality.

According to Wiberg and Robles (2010), then this challenge is also familiar to interaction design: ”… a central problematic concerned with reconciling the digital and physical has always shaped the field” (Wiberg & Robles, 2010, p. 65). This challenge is given an aesthetic direction by Löwgren (2009) who writes: ” The community is increasingly recognizing that an interaction esthetic needs to be dealing with the temporal aspects, the behaviors, the way the interaction feels over time” (Löwgren, 2009, p.144). More recently, then the challenge was addressed at a panel-session on ”Materiality” at the 2012 ACM CHI conference where Anna Allgårda stated: ”A material perspective offers richer aesthetics and new forms of interactions for technological designs” (Wiberg, Ishii, Dourish, Vallgårda, Kerridge, Sundström, Rosner, & Rolston, 2013, p.57). I should like to discuss this challenge to interaction design in pespective of functional animation.

I have, in the previous text, purposely avoided the term virtual as it denotes artificiality and distance. I do not view digital products as artificial or removed from physical reality. Löwgren and Stolterman (2004) use the term ”digital artifacts” as it encapsulates both the physical and the digital materiality of the entities, that I, in this dissertation, have referred to as ”interactive digital systems”. These entities have a physical presence – smartphone, laptop, tablet, watch, etc. and they have a digital presence. The digital and the physical presence are integrated into this interactive digital system which has the basic purpose of enabling access to and handling of information. The term ”information technology” thereby makes a lot of sense. Löwgren and Stolterman (2004) argues that digital technology is the material of designers of digital artifacts and this material can be described as a ”material without qualities” (Löwgren and Stolterman, 2004, p.3). Digital technology is a material without any qualities.

I should like to slightly modify this view of material for interaction designers. The material is not digital, but information in the shape of bits and bytes. The material is not the technology, but the digital format of bits and bytes which renders information indefinitely versatile. Which is also the argument for referring to this material as ”without qualities”. Digital materiality is an information materiality which refer to the versatility of digital technology in manipulating information.

Part III established that the material of animation is movement and it has been established that animation has a particular relation to reality because movement is the phenomenon that denotes life. ”If it moves, it's alive” as filmmaker Segey Eisenstein supposedly said. Functional animation bring this ability of bestowing into the digital material and the digital material embrace it. Like it does most formats. Movement become one of the qualities of the material ”without qualities”. The digital material therefore also becomes capable of bestowing life.

A central aspect of this bestowing of life is the control of time and space. Aspects that Löwgren (2009) point to and actually have defined as central to the digital material when he in 2007 modified the material without qualities to some qualities that Sheets-Johnstone would agree to: ”… interaction design deals with a material with rather unique properties: Digital design materials are both genuinely temporal and genuinely spatial” (Löwgren, 2007, p.70). Functional animation offer a theoretical explanation and a practical approach to utilise these qualities of digital materiality.

Using digital material to create products give these products the qualities inherent in the digital material. Products built with digital material will also constitute a digital reality. A reality which is no less real than products build by materials from physical reality.

The specific product quality is defined by the information that it reference and how it is presented and the digital material allow the construction of realities that would not be possible if this format was not available. Some entities from physical reality have transformed, or made an evolution into digital reality – calenders, contact-lists, typewriters, etc. Other entities only exist in a digtal reality. I usually ask whether people would print Facebook pages to make them more real? The answer is always ”No”. Probably because Facebook is a product that exist only because of digital material qualities. Facebook is as real as a rock in the field. Another example is that of a photograph. Most photograhs are created digitally and never leave the digital environment. Some of us are old enough to think of a photograph as real when it is printed. The digital incarnation is not quite ”right”. Technologist Kevin Kelly shared the following anecdote about a toddler just capable of speaking, who had taken over the familiy iPad and gotten used to browse and manipulate images through gestures. One day a printed photograph was on a table and the toddler started gesturing on the image, but no reactions from the image – it maintained size, position, orientation, etc. So after a few attempts the toddler exclaimed her judgement over the printed photograph: ”Broken!” (Kelly, 2011). The tablet only experience with images indicate that the little girl did indeed think the printed photograph was broken as it did not exercise any of the expected capabilities that she knew from the tablet. She saw the interactive and dynamic capabilites of the digital image as innate properties of ”an image”. Her idea of an image was for it to be interactive and manipulable (Lund, 2012). The digital materiality of an image have affordances to the girl that clearly made her think of the printed photograph as not ”a real image”. This examplifies how the digital characteristics designed into information affects our perception of these digital objects, and thus underscores the responsability of the digital designer. A responsability also noted by Löwgren and Stolterman (2004). The digital designer must know the material and shape information by the qualities of this material. This is a process similar to that of other crafts, as also noted by Wroblewski (1991): ”Creating a human-computer interface is usually, and perhaps always, a craft, because of the investigative nature of each designing” (Wroblewski, 1991, p.17). Craftsmanship is knowing your material.

J.J. Gibson (1979) provide a model of physical reality by his description of the terrestrial environment as mediums, substances and surfarces. In this perspective, then digital materiality and the products created, the interactive digital systems (digital artifacts), constitute a novel physicality. Movement provides this physicality as is allows motile behaviour of the objects and interactivity allows for manipulation and exploration of this physicality. The surface of a touchscreen is an environmental surface of a substance, just like any other non-digital object is a substance with a surface with certain characteristicas. The WIMP GUI is also a physiclaity, but crafted for manipulation to be handled via a proxy. In the case of touchscreens, then the little girl percieves the glassplate as the correct material surface of an image. She does not distinguish between the image and the glass. She does not perceive the iamge as ”below the glass”. In her world, *this* is a photograph. She is thrown in her perception of reality when these wellknown characteristics of reality are missing. Löwgren (2007) introduce the notion of *pliability* as part of the digital aesthetic and describe how ”The pleasure of pliability is found in the feel of the tools as well as in the outcomes they produce” (Löwgren, 2007, p. 79). This is further explained by Löwgren (2009): ”When an interaction feels tightly coupled and highly responsive, almost to the point of shaping a malleable material with your hands, then the interaction experience is one of high pliability” (Löwgren, 2009, p.133). In perspective of functional animation and how the qualities of motion are both shared and mastered within the digital material, then there is an overlap in the pliable aesthetic and the effects of functional animation. Movement as a design component is what make possible the pliable aesthetic. Löwgren (2007) analyse three examples to research the presence and nature of pliability and the pliable aspect of all three examples relate to motion:

> The examples I have used above to explore the notion of pliability, however, seem to mix exploration and reliance – and even make a virtue out of it. Consider the way I discuss zooming in Google Earth as a visceral experience. Or the qualities of the augmented Picasa

> scroll bar. Or the subtle animations in the Visual Thesaurus Löwgren (2007, p.79).

These three examples all use the motile element as an argument for the pliable aesthetic: Zooming, scroll and ”animations” (using principles hint, transition and transformation). Pliability is not functional animation, but functional animation is an essential component in creating this aesthetic. The study reported in Part II could be viewed as researching not only motion, but also pliability. The respondents reported the pliable experience of the five objects in relation to material feel and experiential quality.

The product of Apple, Google and Mirosoft are manifestations of possible physicality of touchscreens. These manifestations shape expectations and understandings of information. Not only on a semantic level, as content, but also in terms of how information should behave and be perceived. Just like the GUI and desktop metaphor shaped current understandings of interaction on this platform. The ethical question is: How would we like information to behave, what reality do we desire?

The materiality of information offered by digital technology is comparable to the invention of the printed book for creating texts and the photo-camera for creating instant images. These new formats allowed new ways of creating, accessing and manipulating information. But no-one probably referred to the printed book or a photography as ”virtual reality”, as if they were not real. Different materiality, different possibilities, but very real.

What separates digital technology and thus the materiality offered, from other formats of information, like the book and the photograph, is interactivity. The digital material allow designers to create information environments that have the dynamics of physical reality. Some of the attributes of physical reality are recognised and others are not quite (or very far from) known physical reality. This is where the notion or virtuality enters the characterisation of digital environments. But by this characterisation we also remove ourselves from properly understanding and utilising the digital material. The challenge that interaction designers should avoid.

The digital material has two aspects: It allow rendering and manipulation of information and it allow construction of the functional environments within which the information is rendered and manipulated. Digital materiality is at the same time material for constructing of both tool and content. Design approaches like ”Mobile First” (Wroblewski, 2011), Googles material design principles (Google Inc, n.d.), Apple iOS (Apple Inc, n.d.a) and Flat design (Marchotte, 2011) all allow content (information) and interface to merge. Setting up a call from an iOS device will happen by pressing the number, not a green button named ”Call”.

Digital is the material for all elements in the communicative process and it enables manipulation of the information moving around in this communicative process. A digital object might be both content and tool at the same time, or the nature changes dependent on circumstances. The cover image of my Windows Phone is an image that I have captured myself on that very same device. I like to watch it when the Phone is idle and on top of the image are date, time and calendar events listed. When I have to access the functionalities of the device, I press my finger at the bottom of the image and slide the image upwards. It is now no longer just an image, it is also a lid, or a feedback mechanism to tell me that I'm about to activate the device. The image has transformed from a role of content and source of enjoyment to a functional role. The movement of the ”image-lid” also informed me where the image went – it is not gone. Needless to say then movement is an important component in this process. The transformation is at one time both radical, and significant to digital reality, but at the same time very basic as the image by its motile quality upon exploration revealed characteristics not immediately perceptible. This brings us back to the ecological understanding of perception where the human explores the environment and discover possibilites for meaningful action.

The digital material allow the construction of rich environments. Environments that in their interaction are quite similar to how humans negotiate environments in physical reality. Moving the image on my phone is comparable to moving a rock to look for edibles. The image, like the rock, affords moving. Having added movement to the repertoire of design components have enabled the construction of digital realities, environments that feel and behave natural from a human perspective, with a pliable quality, even when they concern something as abstract as information.

Gene Youngblood said: ”We shall learn to desire the realities we simulate by simulating the realities we desire” (Youngblood, 1982, p.3). But digital realities, the environments, complex and simple, constructed in the digital material, are as real as physical reality. They are not simulations. These environments however, should be desireable environments and they should not as Arthur C. Clarke said: ”… be indistinguishable from magic”, but indistinguishable from reality and make information as accessible and manipulable as physical reality. That is what humans as mindful bodies are attuned to. Interaction designers must design with and for information to be explored, found and manipulated.

23 CONCLUSIONS

This section will address how the research results answer the research question established in Part I. The overall goal was to verify the hypothesis of functional animation. The hypothesis consist of four statments:

1. *The context of interactive digital systems constitute a particular use of animation.*

2. *The interactive and task-oriented nature of interactive digital systems makes this use of animation significant compared to other contexts of use.*

3. *Animation as the craft of manipulating motion, and movement as the resulting phenomenon, are fundamental to the quality of this interaction.*

4. *The term Functional Animation is proposed for this particular use of animation.*

Eight research questions were established and corresponding research activities were performed. The following is a summary of the results and an evaluation of how these inform the hypothesis.

23.1 Q1 Animation studies

How does functional animation position itself in relation to other uses of animation?

The question required an overview of types and usages of animation in a scientific persepctive. A review of existing understandings of animation studies and in particular the proliferation of digital technology lead to the proposal of a model for animation studies that view animation as an cross disciplinary field. The model establish the particular uses of animation as the intersection of two dimensions. One dimension distinguish between linear and interactive animation and propose a set of purposes within these types. One of these purposes is user interfaces. The other dimension is the various context within wich animation is applied. The contexts are represented by fields and within these a variety of disciplines. This leads to the TPFD-model (Type-Purpose-Field-Discipline) that establish functional animation as a particular use of animation characterised as *Interactive animation for user interfaces within the field of design and the discipline interaction design.* The model allow precise discrimintation of functional animation in relation to other particular usages of animation.

The results of the research answer the research question and verify that functional animation is a particular use of animation.

23.2 Q2 Animation and interactivity

Does the interactive context require a different understanding of animation?

Seven definitions of animation from both animation scholars and practitioners and from outside the field of animation were researched to establish a common understanding of the phenomenon animation. A definition of interactive animation was added to this set as no established definition was available. Following this a generic and modular definition of animation was proposed that covers both linear and interactive animation and allow the contextuality of animation usage established by the TPFD-model to be considered when defining animation. The basic understanding of animation practice and the essence of animation as ”the illusion of life” does not change within functional animation, but functional animation appear to be an essential component in establishing the interactivity of digital artifacts.

The results of the research answer the research question and strongly suggest that functional animation is essential in establishing the interactivity of digital artifacts.

23.3 Q3 Overlap in histories

What are the rationales for including animation and movement in interaction design?

The question required a historic account of how and why animation has entered the interaction design discipline (and visa versa). The history of animation was unfolded by an account of not only the technical and artistic development, but supplemented by an account of how the realisation of imagined realities so siginificant to animation was also present in paleolithic cave paintings. This excursus was performed to address the persistent reference in animation literature to cave-paintings as proto-animation. The research showed that this is not the case. The historic account showed how animation and movement as a design component has been a conscius part of interaction design since the 1973 version of the Xerox Smalltalk software that also lay the foundation for the WIMP GUI paradigm. The rationales for including functional animation have been the ability of animation to provide a physical feel, to allow fluent manipulation of content and interface elements and to communicate changes in state, location and functionality. The result being added efficiency and satifaction of system use and a physicality in system aesthetics. This account of overlapping histories between animation and interaction design has not been described before. The historic account also showed, that the use of animation as a component in unison with other components for a functional purpose, is unique.

The results of the research answer the research question and illustrate the particular use of movement within interaction design and the overlapping relationship between animation and interaction design.

23.4 Q4 Unification of design principles

What are the design principles for functional animation?

To research this question a general model for design components ranging from the very concrete *primitives* to the most abstract *values* is proposed. Functional animation principles are defined as purposes of motility to support the general system principles. A set of functional animation principles are proposed based on a heuristic merger of a recognised theoretical set of principles and a historically recent practice based set of principles. This merger produce a set of seven new principles. A set of guidelines based on an existing reference is presented and a set of three values for guiding functional animation design is proposed.

The results of this research are proposals that represent a preliminary investigation of the research question. The results have not been researched or evaluated in practice. The results indicate the presence of uniqe principles for functional animation that will support both research and practice activities.

23.5 Q5 Framework for design and documentation

How could design principles manifest a framework for design, documentation and communication of movement in the design and development process?

To answer this question a preliminary model that relates the principles of functional animation to concrete interface elements is proposed. The model builds on the understanding of functional animation as relational between action and re-action. The modal illustrates the potential practical application of functional animation design principles in the work with concrete motile patterns. The framework thereby represent a proposal for transfer of theoretical understandings into an applied practice.

The result of this activity is a proposal that represent a prelimiary investigation of the research question. The result have not been reserched or evaluated in practice. The result indicate a potential path for practical application of functional animation as established by this dissertation.

23.6 Q6 The meaning of motion

Does motion generate meaning?

To answer this question an empirical research study was established that had 188 respondents report their experience of 5 visually identical, but motionally different objects. The integrated exercise represented an abstract de-contextualised system model to target movement as an isolated phenomenon. The research question was supported by a hypothesis that specifically oriented this study towards motion in the interactive setting of touch screen technology. The study is reported and concluded in Part II and provides an empirical foundation for movement as an independent factor for meaning in the context of interactive (touchbased) digital systems and a foundation for existing and future research and application of functional animation within specific contexts. The research method applied appear to be uniqe as it allowed an interactive exercise to be integrated into a quantitative survey which was then distributed via the ”app.-model” and thus liberated respondents from a particular research setting. The entire data collection process took place in a digital ”pipe-line”.

The results of the study provide an empirical foundation for contextual usages and research of interactive user interface animation as established in this dissertation by the concept functional animation.

23.7 Q7 Implications

What are the implications of functional animation for interactive digital systems?

Answering this research question is in principles without scope. An answer that discuss the relation between interactive digital systems and physical reality is provided. It is argued that digital materialty by the inclusion of functional animation creates a reality that is no less real than physical reality, but characterised by the form given by designers to information by their moulding of the digital material.

The discussion contribute to the understanding of functional animation as a a particular area of both practice and science.

23.8 Q8 Research agenda

What is the research agenda for functional animation?

Answering this question is addressed by a description of 13 potential research areas within functional animation. The potential within these research subjects indicate that establishing functional animation as a particular area and concept is valuable to both animation and interaction design.

The research agenda contribute to the establishment of functional animation as a particular area of both practice and science.

The collected set of results uniformly establish the presence of functional animation as a particular use of animation in the context of interactive digital systems. This particularity is rooted in the interactive and task-oriented nature of interactive digital systems. The research results also strongly indicate that animation as the craft of manipulating motion, and movement as the resulting phenomenon, are fundamental to the quality of this interaction. The term *Functional animation* is proposed for this particular use of animation and should thereby provide a concept for existing and new research and practice activities witin the area overlapping both Animation and Interaction design.

Movement represents a fundamantal component in interaction design. Functional animation represents the overlap between animation and interaction design where both research and practice should develop theories concerning this phenomenon.

The following section will highlight the contributions provided by this dissertation. The contributions are within three overall categories: Theoretical, practical and methodological.

23.9 Theoretical contributions

The concept of functional animation is a contribution to *both* animation and interaction design research as it represents a concept and an area for collecting knowledge about the use of movement within animation and interaction design.

Functional animation is itself a constribution as it represents an independent area of research consitutued by the overlap between animation and interaction design.

The study reported in Part II is a contribution to *both* animation studies and interaction design as it provide empirical data on the basic meaning of motion within an interactive digital system.

The set of merged principles for functional animation is a contribution to *both* animation studies and interaction design as it represents a new and unified set of understandings of what movement can do in the user interface.

The description of the overlap in histories between animation and interaction design is a contribution to *both* animation and interaction design as is describes a hitherto unnoticed relation between the two fields of practice.

The TPFD-model is a contribution to animation studies as it represents a novel view of the field of research. Including a typology of linear and interactive animation.

The definition of interactive animation is a contribution to animation studies as this represents an understanding of this particular type of animation.

The modular and contextually based definition of animation is a contribution to animation studies as this represents an understanding of animation that envelopes the digitalisation of animation practice.

The description of the overlap in histories between animation and interaction design is a contribution to animation studies as it documents the novel use of animation within the functional setting of a tool.

The dismissal of cavepaintings as proto-animation is a contribution to animation studies as it provides insight into a wide-spread misunderstanding, while reframing the relation between animation and cave paintings.

23.10 Practical contributions

The concept of functional animation is a contribution to *both* animation and interaction design practice as it represents a concept and an area for collecting and accessing knowledge about the use of movement within interaction design

The framework for functional animation design, documentation and communication is a *preliminary* contribution to *both* animation and interaction design practice as it allow designers to contemplate the design of functional animation.

23.11 Methodological contributions

The integrated metod used for the ”meaning in motion” study is a contribution as it allowed distribution of both questionnaire and interactive survey within the same (digital) setting. Adding to this is the notion of de-contextualisation to target the phenomenon being resaerched.

Further research into this method, that describe, evaluate, and standardize the approach for experimental data-collection could be performed. The method appear promising for phenomenological research that combine quantitative and experiential exploration.

24 PERSPECTIVES

This section address research question 8: *What is the research agenda for functional animation?* by proposing the following areas of research within functional animation.

1. Animation studies

This dissertation propose novel views on animation studies and the animated form.

The TPFD-model and the modular definition of animation, and the definitions of linear and interactive animation. These proposals should be further discussed.

The perspective of this dissertation has been that of interaction design because of my professional perspective and experience. Animation studies should also consider research into interaction design. An animators view on interaction design could produce new understandings upon the design of interaction.

2. Interactive information visualization
Research into data visualisation and functional animation was initiated by research on the Cognitive Coprocessor (Robertson, Card & Mackinlay, 1989). Data visualisation is a field kindered to interaction design, as also noted by Löwgren (2007). The familiarity gets even closer when Ferster (2013) introduce interactive visualization. My expectation is that the fields interaction design and interactive visualization will merge. The principles of Mobile First (Wroblewski, 2011) bring information to the front of the interface. The presence of motion in these interactive spaces will increase. Research into information visualization therefore represent a relevant area for functional animation. This perspective builds on the persepctives laid out in the Discussion (section 22).

3. Education of Animators and Interaction designers
Functional animation should be considered as subject for the curriculum for educating animators and interaction designers. An extension of this curriculum could make functional animation the subject of an extension to the education of Animators and Interaction Designers. This option could alse include experienced and practicing professionals. This would not only disseminate the concept, but also challenge the knowledge within the concept

4. Principles, Guidelines and Motile patterns
The principles of functional animation should be researched in relation to the system principles. This would allow a better integration of motion into system principles. System pricniples are in their current incarnation a result of first wave HCI. The interface design guidelines found in the Xerox Star Red Book have not changed much since the mid 1970'ies. The Guidelines for practical design should be researched in relation to interaction paradigms like NUI. The set of guidelines proposed is derived from WIMP GUI (Thomas & Calder, 2001). The concept of motile patterns and motion gestalts should be further researched to clarify the possibility of establishing generic motion-compounds (Figure 62). This research would continue the effort started in section 19.2.

5. Functional animation frameworks
Section 20 proposed a framework for designing, documenting and communicating functional animation. The proposed framework was also suggested as a tool to inspire and support sketching of functional animation. This proposal should be further researched and refined. This research should be performed as a practice based activity to obtain a result that is not only theory, but also enable, support and progress the use and understanding of functional animation

6. Affective effect of functional animation

Park and Lee (2010) and Park, Lee and Kim (2011) address the affective value of functional animation. This line of research could be further pursued and the knowledge integrated into the principles and guidelines for functional animation.

7. Functional animation and VR and AR

The meaning of movement in areas like virtual reality, augmented reality and kinetic environments should be researched as these areas are addressing the same overlap to reality as animation is negotiating.

8. Functional animation in touch environments

The research presented in this project is focsed on establsihing functional animation. The empirical data is collected via touchscreens, but the aim is not to understand touch interaction. But the study results and the central role ascribed to motion in styleguides (Google Inc., n.d.; Microsoft Inc., n.d.; Apple Inc., n.d.a.; Apple Inc., n.d.ab) and on-line practices oriented texts (section 6) indicate that motion is an important component for touch screen interaction design. The area could benefit from a dedicated effort. A hypothesis is: Motion is an indispensable component of and for touch screen interaction. Much of the answer seems to lie within the NUI paradigm, but publications like Wigor and Wixon (2011) are not explicit on the dependecy on movement. The research presented in this dissertation could be a platform for this effort.

9. Functional animation and sound

The relation between movement and sound could be researched to understand how sound affects the experience of movement.

10. Physical context and functional animation

This research would be directed at the effects of physical context on the use of functional animation in design of interaction for mobile devices. Context could both the general physical setting og use and it could be the physical context of the artifact shape and material. Such research could for example address curved touch displays. Could functional animation influence the demarkation between physical and digital reality?

11. Functional animation and somatosensory perception

This research would address the relation between functional animation and somatosensory stimulants like tactile and haptic feedback. This dissertation has established that functional animation is relational, so the addition of an extra sensory stimulant will affect this relation. This somatosensory stimulant could be a forcesensitive display like the Apple iPhone 7. Alternatively the use of trembler/buzzer as somatosensory stimulant. Park, Lee and Kim (2011) have started this work. An alternative line of research could be the use of somatosensory stimulants to envoke the perception of movement, not as support of functional animation, but as a source of motile patterns itself.

12. Functional animation in perspective of Ecological Psychology

This dissertation has involved the ecological approach to perception by J.J.Gibson (Gibson, 1979). A dedicated research effort into the meaning of movement within a ecological framework would further the understandings of movement and how to apply this phenomenon in digital ecologies.

13. Animation and dissemination of research

The use of paper for disseminating research has expressive limitations. Movement is not only a rich media for communication. It is also useful in conjunction with other experessive formats. Daliot (2015) is a simple example of this as the online nature of his text allow animated examples to be embedded into the text. A highly useful feature to better understand his categories. Integrating the animated form into dissemination efforts would be useful and sensible. The theory-practice gap could also be challenged by a communicatively richer approach to research dissemination. This approach also implies potential consequences for other areas of research within media studies, but possibly also for research in general.

The scientific aim of establishing functional animation has been a well defined concept *from which* to conduct research; and *into which* to contribute this research – to paraphrase Frayling's categories of design research (Frayling, 1993). Establishing functional animation as the proper reference in conversations and publications about interaction design and animation require further research and dissemination. The concept must be presented, understood and accepted within the science and practice communities of both interaction design and animation. This will be the next step upon completing this project.

25 ENDNOTE

The focus of the dissertation has remained in the interests of the four project-partners. My hope is that: 1) The Animation Hub will see the potentials of animation unfolded within the area of interaction design and thus how animation has value beyond the traditional areas of application. 2) The Animation Workshop will seize the opportunity to integrate functional animation into the student curriculum. 3) Nokia and Bang & Olufsen will accept the theoretical and practical results and integrate functional animation into their product development process. 4) The Department of Communication and Digital Media at the University of Aalborg will support further research within functional animation and allow me to integrate this knowledge into the educational curriculum. 5) The community of Interaction design practice and science will apply and extend the understandings and implications of functional animation. 6) Animation scholars and practitioners will embrace, discuss and extend the proposals within animation laid out by this dissertation.

You never change things by fighting the existing reality.To change something,
build a new model that makes the existing model obsolete.
R. Buckminster Fuller

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APPENDICES

Appendix A. Questionnaire from quantitative survey - English version

This appendix presents the questions used in the quantitative survey of the experience of motion. The questions are presented as they appeared in the questionnaire in the iOS app. Only one question was presented per page to prevent scrolling.

The english version of the questions was not used for collecting data. All respondens were danish speaking and data was collected via the danish version (available upon request). This english version is presented to make the data accessible to non-danish speaking readers. The english version was also used as foundation for the english wording used when the data-set was imported from Google-forms into the data visualisation tool Tableau.

Translated by Morten Lund. Semantic discrepancies between versions are therfore mine alone.

The questionnaire

AALBORG UNIVERSITY, INTERACTIVE DIGITAL MEDIA 2013

Thank you for participating in my experiment.

The experiment investigates the design of user interfaces for touchscreens. It will take about 20 minutes to complete the experiment. All answers are 100% anonymous.

The experiment consists of a questionnaire in 2 parts and an exercise. The exercise is very simple, and the goal is not to complete the task quickly or without errors. Focus is on the object you use for the exercise.

Please enjoy - I look forward to receiving your answers!

Press ‘Fortsæt/Continue’ below to proceed to questionnaire part 1.

Sincerely yours
Morten Lund

mlund@hum.aau.dk
PhD Candidate
Interactive Digital Media, Aalborg University

1|8 - Gender & Age

☐ Man

- [ ] Woman

- [ ] 0-4
- [ ] 5-9
- [ ] 10-14
- [ ] 15-19
- [ ] 20-29
- [ ] 30-39
- [ ] 40-49
- [ ] 50-59
- [ ] 60-69
- [ ] 70+

2|8 - Please enter your most recently completed or ongoing education.

- [ ] Kindergarten
- [ ] Public school
- [ ] High school or similar
- [ ] Technical college or similar
- [ ] University
- [ ] Self-educated
- [ ] Other

3|8 - Please indicate whether you have experience with the below digital technologies.
Answer 'yes' even if you have tried only once.

	Yes	No	Don't know
Computers operated via keyboard and mouse (or similar)			
Xbox, PlayStation, or similar			
Microsoft Kinect, Nintendo Wii, or similar			
PSP, Nintendo 3DS, PlayStation Vita, iPod, (or similar)			
Mobile phone without touchscreen			
iPhone			
Other smartphone (Samsung, HTC, Nokia, Sony, or similar)			
iPad or iPad Mini			
Other Tablet (Android, Windows, or similar)			
e-Book reader (Kindle, or similar)			

4|8 - How do the following statements match your attitudes to digital technologies?

	Yes	Neutral	No	Don't know
I think digital technology is interesting				
I try to be among the first to try new digital technologies				
I learn to use digital technologies as the need arises				
Digital technologies are an integrated part of my life and my activities				
I am aware, that the technology I use, is digital				

5|8 - Which digital technologies do you prefer for your activites?
You can state preference or no preference for as many options, as you like.

	Prefer	Neutral	Prefer not	Not relevant
Stationary computer				
Laptop computer				
Tablet (iPad, or similar)				
Smartphone				
Ordinary mobile phone				
Hand-held gaming console (PSP, iPod, or similar)				
Stationary gaming console (Xbox, Wii, or similar)				
Other				

6|8 - How often do you use devices with a touchscreen?
Touch sensitive screen are also referred to as "Touch-screens". It is screens that react upon pressure by one or more fingers.

	Daily
	Weekly
	Now and again
	Rarely
	Never

7|8 - How do the following statements match your experience with touchscreens?

	Yes	Neutral	No	Don't know
I try to avoid touchscreens				
I think touchscreens are cool				
Touchscreens make me want to use digital technology				
Touchscreens are difficult to use because I can't see what can be pressed and pushed				
I experience touchscreens as dynamic and full of movement				

8|8 - The statements below all begin with "When I use a touchscreen…

	Yes	Neutral	No	Don't know
… it is easy to keep the overview of the activity"				
… I have a good sense of what I am doing"				
… I have a good sense of what happens and what will happen"				
… I often make mistakes"				
… I am afraid to make mistakes"				
… I find it easy to become seized with the activity"				
… I want to examine and play with the content"				
… I like that it is my fingers that I use for the activities"				

END OF QUESTIONNAIRE PART 1
You have now completed part 1 of the questionnaire and must proceede to the exercise

PLEASE READ THE FOLLOWING INSTRUCTIONS THOROUGHLY !!

1. The exercise consists of 3 courses
2. In in each course you must move a circle onto an X
3. At the bottom of each course the numbers 1, 2, 3, 4 and 5 are listed. You change circle by pressing these numbers.

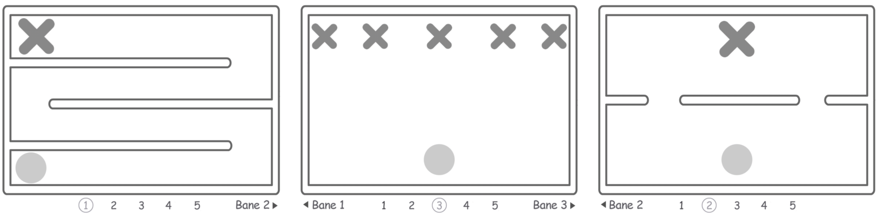
4. Each course must be completed with both 1, 2, 3, 4 and 5 – that is to say 5 times

PLEASE NOTICE: The aim of the exercise is not to complete the task quickly or without errors. Focus is on the object you use for the exercise.

You may complete the exercise as many times as you please.

Press the blue button 'GÅ TIL ØVELSEN/GO TO EXERCISE' (top right corner) to go to the exercise.

At this point the respondent is presented with the three course exercise that establishes the foundation for part 2 of the questionnaire.



START OF QUESTIONNAIRE PART 2
The questions in part 2 concerns the circle and your experience of this.

PLEASE NOTICE !
Press the blue button 'GÅ TIL ØVELSEN/GO TO EXERCISE' in the top right corner of the screen if you wish to revisit the exercise.

Press the button 'Fortsæt/Continue' below to go to questionnaire part 2.

1|13 - Did you experience different versions of the circle?
e.g. did you experience '1' as different from '2', or that '3' was different from '5'?

☐ Yes
☐ No

If 'yes', then what gave you this experience of difference?
Your answer need not be exact, just a reflection of your immediate impression.

	Yes	No	Don't know
Hard/easy to move			
Change of shape			
Change of size			
Reaction			
Colour			
Sound			
Other			

2|13 - How many different versions of the circle did you experience?
Your answer need not be exact, just a reflection of your immediate impression.

	None
	Two versions
	Three versions
	Four versions
	Five versions

Mark the degree of difference between the versions you experienced

	0	1	2	3	4	5	6	7	
No difference									Very large difference

3|13 - Did you experience one or more of the circles as 'sluggish' or 'inert'?
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Circle **1**
	Circle 2
	Circle 3
	Circle 4
	Circle 5
	None

4|13 - The below statements commence with: "All the circles …"
Please note your agreement or disagreement. Answer 'don't know' if you're in doubt.

Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Yes	No	Don't know
... have the same colour			
... are without sound			
... can be moved (Danish: trækkes)			
... can be flicked (Danish: kastes)			
... behave alike when moved (Danish: træk)			
... behave alike when flicked (Danish: kast)			
... reminds me of different materials			
... are equally easy to use across the 3 courses			
... have similar reactions when pressed upon			
... have similar reactions when released			
... have similar reactions upon impact w. wall or barrier			

5|13 - Please state preference and not preferred

Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

Indicate the two circles you liked THE MOST

	Circle **1**
	Circle 2
	Circle 3
	Cirkel 4
	Cirkel 5
	None

Indicate the two circles you liked THE LEAST

	Circle **1**
	Circle 2
	Circle 3
	Cirkel 4
	Cirkel 5
	None

6|13 - Certain properties are absent from all versions of the circles.
Please state whether you noticed the abscense of these properties.

	Yes	**No**	**Don't know**
Did you miss sounds?			
Did you miss colours?			
Did you attempt tilting or shaking the screen (to move the circle)?			

7|13 - Did one or more versions of the circle resemble a specific MATERIAL?
Please state which version of the circle that resemble which material.
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Metal	**Rubber**	**Sponge**	**Paper**	**Other**	**Nothing**
Circle 1						
Circle 2						
Circle 3						
Circle 4						
Circle 5						

8|13 - Did any of the below actions lead to the impression of one or more versions of the circle resembling a MATERIAL?
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Push/Pressure
	Pull
	Collision
	Slip
	Flick
	Slide
	Rebound
	None
	Don't know

9|13 – Did you expereince one or more versions of the circle as exhibiting a certain CHARACTERISTIC?

Please state which version of the circle that could be described by which characteristic.
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Kind	Annoying	Apathetic	Lively	Other	None
Circle 1						
Circle 2						
Circle 3						
Circle 4						
Circle 5						

10|13 - Did any of the below actions lead to the impression of one or more versions of the circle to exhibit a certain CHARACTERISTIC?
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Push/Pressure
	Pull
	Collision
	Slip
	Flick
	Slide
	Rebound
	None
	Don't know

11|13 - The below statements concern the relation between the circle and the courses
Press the button 'Gå til øvelsen/Go to exercise' in the top right screen corner, if you wish to revisit the exercise.

	Yes	Neutral	No	Don't know
I recognised the different versions of the circle across the 3 courses				
The layout of the 3 courses helped me identify more versions of the circle				
One or more versions of THE CIRCLE AFFECTED my impression of the COURSES POSITIVELY				

One or more versions of THE CIRCLE AFFECTED my impression of the COURSES NEGATIVELY				
My experience of one or more versions of the circle CHANGED IN A POSITIVE DIRECTION during the courses				
My experience of one or more versions of the circle CHANGED IN A NEGATIVE DIRECTION during the courses				

12|13 - The below statements concern your impression of the exercise
Answer 'Yes' if you agree, and 'No' if you disagree.

	Yes	Neutral	No	Don't know
I think the exercise was difficult				
I was aware that I was using a touchscreen				
I was aware that the exercise was executed on digital technology				
I felt like playing with one or more versions of the circle				
One or more versions of the circle were annoying				
One or more versions of the circle were too sluggish for the exercise				
One or more versions of the circle were too lively for the exercise				
It felt natural to use my fingers for the exercise				

13|13 - How did you reach your answers?

	Yes	No	Not relevant
Did you return to the exercise and try again?			
If yes, did this then change your impression of one or more versions in a POSITIVE direction?			
If yes, did this then change your impression of one or more versions in a NEGATIVE direction?			
If yes, did this then change your impression of the number of versions of the circle?			

The test is now complete.

IMPORTANT: Press the button 'SEND/SEND' to register your answers and close the experiment.

You may now remove the app. If other people must also complete the experiment, then you just have to restart the app.

Thankyou for your time and participation!

Sincerely yours
Morten Lund

mlund@hum.aau.dk
PhD Candidate, Interactive Digital Media
Aalborg University

Appendix B. Interviewguide for Participatory design sessions

DANISH ONLY

Hypoteses:

- *The importance of animation in user interfaces increases with the degree of interactivity*
- *Animation enables the creation of a simulated materiality.*
- *Animation will bring digital representations closer to the physical world and thus the human closer to the digital representations.*

Øvelsen er et forsøg på at omsætte et skærmbaseret eksperiment om forholdet mellem animation og interaktivitet til den fysiske verden.

Giver øvelsen mening i forhold til at undersøge dette ?

Hvad betyder materialitet ifht oplevelsen af øvelsen ?

1. Giver øvelsen mening ?
2. Hvad oplever du når du laver øvelsen ?
3. Er øvelsen bedst med eller uden forhindring ?
4. Kunne du forestille dig denne øvelse på en berøringsfølsom skærm ?
5. Hvis du skulle foretage øvelsen på en berøringsfølsom skærm hvad ville du så gerne spørges om ?
6. Er der forskel på de forskellige objekter du flytter ?
7. Beskriv forskellen ?
8. Kunne du forestille dig disse materialer på en berøringsfølsom skærm ?
9. Ville det give mening ?
10. Er der materialer du synes, man skulle prøve at efterligne i det digitiale forsøg
11. Mener du, at testen giver svar på de forsknings-spørgsmål jeg stiller ?
12. Gør det, det nemmere for dig at svare ærligt på spørgsmålene, at du ved hvad jeg undersøger ?
13. Eller føler du, at testsituationen gør dig usikker på det du oplever ?
14. …

Appendix C. Research activity: Movement in contemporary mobile touch devices

The results of this study are in Appendix D.

This appendix describe the research activity.

This empirical study was performed in Q2 & Q3, 2010. The study was motivated by the disrupted state of the mobile handset market at the time. The aim was to produce *insight into state of the art design of movement, in mobile devices* by investigating competitor products. The method was to create samples of movement and then compare these samples.

A state of the art investigation establishes a baseline for current standard within an area. This defines the level of performance in respect to certain parameters and allow gauging of what is minimum to be on par with similar products. Both Nokia and Bang & Olufsen requested this activity and it seemed like a meaningful first research activity to get a feeling of the concrete implementations of animation in touchscreen devices. No similar research existed.

5 touchscreen devices were selected in agreement with Nokia and Bang & Olufsen based on 1) presence in the marketplace, 2) difference in UI design, and 3) commonalites in functionalities that enabled comparison. The five devices are listed in Table 12.

Device	UI concept
Microsoft Zune Media Player	Microsoft Metro
Apple iPhone 4	iOS
LG Chocholate BL40	LG proprietary
Nokia N900	Maemo
Google Nexus One	Android

Table 12. Devices used for state of the art

Some of the devices were released to the market earlier than 2010, but they still represented top tier devices. Not only in Denmark, but on a global scale. Since 2010 implementations of iOS, Android and Microsoft have gone through quite a few generations, and the proprietary solutions from LG and Maemo have gone extinct.

To settle a baseline then comparable parameters across the devices had to be established. I looked into various user interface patterns (Tidwell, 2010) and idioms (Cooper, Reimann, & Cronin, 2007) that would be available across all five devices. Based on my industry-experience, I selected a set of 41 user interface indicators, actions and events that could be expected to be available across all 5 devices. A subset (30) of these are listed in

Table 13.

	Power on/ off		Keypress
1a	Power on	5a	Open/Close
1b	Power off	5b	Select/De-select value
		5c	Activate/Select
	Stand by	5d	Start/Stop
2a	Un-lock		
2b	Animated wallpaper		**Menus**
2c	Stand By 1tifications	6a	Focus marker
		6b	Icons
	Change state		
3a	StandBy –> Menu		**Event-handling**
3b	Open/Close application	7a	Incoming Call
3c	Open/Close contextual menu	7b	New message
		7c	Alarm
	Scroll	7d	Charging
4a	Matrix horizontal	7e	Prompts & Dialogs
4b	Matrix vertical		
4d	List vertical		**Other**
4e	Full Screen horizontal	8a	Progress
4f	Full Screen vertical	8b	Zoom in & out
4g	Cover flow style	8c	Increase/Decrease value
		8d	Move/Drag item
		8e	Alphanumeric Input

Table 13. Indicators, actions and events documented in state of the art study.

Data was created by video-documenting the 41 patterns across all 5 devices. A videocamera was mounted on a fixed vertical arm and the devices attached with sticky-tack to a board below. 216 individual films were created this way.

This exercise of collecting these films was very interesting as I got to familiarise myself with the devices as I pressed, flicked, pinched and dragged the UIs to identify the patterns to document. Some devices used movement in the selected cases and others did not. But I also discovered that the devices used movement in innovative and unexpected manners, and they did this in cases that were not covered by the selected 41 patterns. Some of these were very illustrative in terms of the way movement was used as a component in creating interaction. It would therefore be incorrect not to keep them for further investigation. But not all cases had matching features on the other devices. This established the dilemma of whether to stick to the selected 41 cases for the sake of comparability or to also document these cases outside the defined set. I chose to create a 42nd case called 'wild card' to document these coincidentially discovered examples. This supported the overall aim of learning about contemporary state of the art. It would not be state of the art, if these examples were missing.

This necessity of a 42nd category exposed mismatches between the research-approach and the project goal of establishing functional animation. If innovative uses were not documented, or not even registered, then how could the potential of movement in interaction design be properly revealed? This was just 5 devices. How about examples of innovative uses on other devices, or other technological platforms and contexts of use? The necessity for a 42nd category exposed a methodological challenge for how to research movement in interactive digital systems.

The overall research appraoch was also problematic in another way Evalauting interacivity as the correlation between user actions and experience of a subtle and ephemeral phenomenon as motion, by presenting respondents with *a video* to comment, could not produce useful data.

Progressing the activity was therefore abandoned.

The videosamples have had illustrative and documental value and the quantitative survey that they represent says that 79% of the documented patterns exhibit movement as part of their design (Appendix D). The suvey thus documents the widespread use of motion as a design component

Appendix D. Results of Movement in mobile devices

Presence of animation

		(Android) Google Nexus One		(Maemo) Nokia N900		(iOS) iPhone/ iPod Touch		(Metro) Microsoft Zune		(proprietary) LG Chocholate BL40	
		Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
		24	6	23	7	23	7	21	5	23	6
	Power on/ off										
1a	Power on	1		1			1	1		1	
1b	Power off	1		1		1		1		1	
	Stand by										
2a	Un-lock	1		1		1			1	1	
2b	Animated wallpaper	1			1		1		1		1
2c	Stand By 1tifications		1		1		1		1		1
	Change state										
3a	StandBy –> Menu	1		1		1		1		1	
3b	Open/Close application	1		1		1		1		1	
3c	Open/Close contextual menu	1		1		1		1		1	
	Scroll										
4a	Matrix horizontal	1		1		1		1			1
4b	Matrix vertical	1		1		1		1		1	
4d	List vertical	1		1		1		1		1	
4e	Full Screen horizontal	1		1		1		1		1	
4f	Full Screen vertical		1		1		1	1			1
4g	Cover flow style	1		1		1		-	-	-	-
	Keypress										
5a	Open/Close	1		1		1		1		1	
5b	Select/De-select value	1		1		1		1		1	
5c	Activate/Select	1		1		1		1		1	
5d	Start/Stop	1		1		1		1		1	
	Menus										
6a	Focus marker	1			1		1		1		1
6b	Icons		1		1		1		1		1
	Event-handling										
7a	Incoming Call		1	1		1		-	-	1	
7b	New message		1	1		1		-	-	1	
7c	Alarm		1		1	1		-	-	1	
7d	Charging	1		1			1	1		1	
7e	Prompts & Dialogs	1		1		1		1		1	
	Other										
8a	Progress	1		1		1		1		1	
8b	Zoom in & out	1			1	1		1		1	
8c	Increase/Decrease value	1		1		1		1		1	
8d	Move/Drag item	1		1		1		1		1	
8e	Alphanumeric Input	1		1		1		1		1	

Sum	Percentage	
114	78,6	**Positive**
31	21,4	**Negative**
145	100	**Total**

Appendix E. Correspondance w. Altamira Cave Museum

Orignal letter

Fra: investigacion.maltamira@mecd.es
Emne: información jabalí 8 patas
Dato: 26. jun. 2012 kl. 13.18
Til: mlund@hum.aau.dk

Estimado Sr.:

En respuesta a su mail sobre el "jabalí de 8 patas", le informamos lo siguiente:

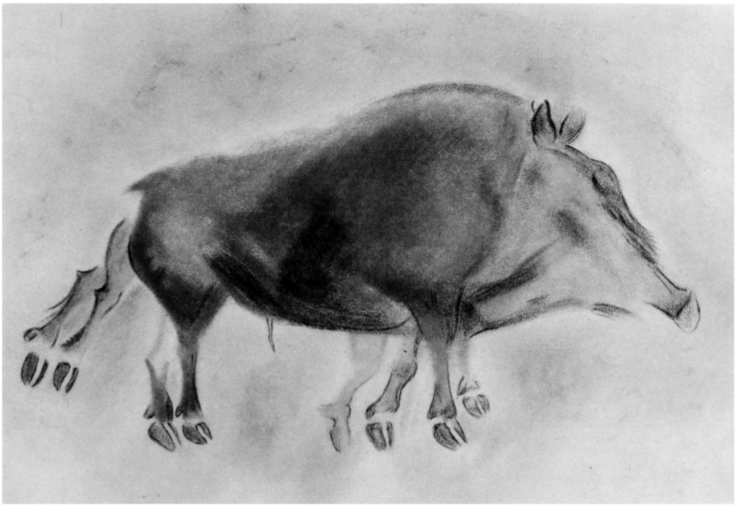
- Actualmente esta figura se interpreta como un bisonte, no como un jabalí. Fue Henri Breuil quien defendió que en el Gran Techo de la cueva de Altamira se habían representado dos jabalíes pero hoy día esta hipótesis no se mantiene

- Efectivamente esta figura se ha usado para ilustrar el movimiento en el primer Arte de la Humanidad. Sin embargo, desde un punto de vista estricto, no podemos confirmar que se trate de una representación de movimiento ya que puede ser una rectificación del artista para colocar mejor las patas o también puede deberse a la superposición de dos figuras. En cualquier caso, no podemos verificar ninguna de las dos hipótesis ya que es una figura poco visible. Fue el Abate Breuil quien realizó el calco de esta figura (Breuil, Obermaier, 1935), que le adjuntamos.

- Recientemente se ha publicado una obra sobre el movimiento en el arte paleolítico que puede ser de su interés. Le recomiendo la obra de Marc Azéma: L'Art *des cavernes en action: les animaux figurés, animation et mouvement, l'illusion de la vie* (Tomo 1, de 2009 y Tomo 2, de 2010). Editions Errance.

Reciba un cordial saludo

Departamento de Patrimonio/Investigación
Museo Nacional y Centro de Investigación de Altamira
Santillana del Mar 39330 Cantabria
Tlf.: + 34 942 81 80 05 (Ext. 235) – Fax: +34 942 84 01 57
investigacion.maltamira@mecd.es



English translation of letter from Departamento de Patrimonio/Investigación at the Museo Nacional y Centro de Investigación de Altamira.

In response to your mail on the "8 legged wild boar ", we can inform the following:

Currently this figure is interpreted as a bison, not a wild boar. Henri Breuil was the one who argued that the Great Ceiling of the Altamira Cave had representations of two boars, but this hypothesis is not maintained today.

Indeed this figure has been used to illustrate movement in the first art of humanity. However, from a strict point of view, we can not confirm that it is a representation of movement as it may be a rectification by the artist to better position the legs or it could be due to the superposition of two figures. In any case, we can not verify either hypothesis because it is a badly visible figure. It was Abbé Breuil who did the carbon copy of this figure (Breuil, Obermaier, 1935). This is attached.

Recently a book on the movement in Palaeolithic art that may be of interest, was published. I recommend the work of Marc Azéma: L'Art des cavernes in action: les animaux figures, animation et mouvement, l'illusion de la vie (Volume 1 and Volume 2, 2009, 2010). Editions Errance.

Appendix F. Project and Personal

This Appendix presents the formal and personal aspects of the Animated User Interfaces project.

Project setup and progression

In the autumn of 2008, the *Danish ministry of Research and Innovation* approved an application for financing the Innovation-network *Animation Hub*[78]. The purpose of Animation Hub was to explore the potential of animation in contexts that extend beyond the traditional areas of application – featurelength films, short films, commercials, music videos, SFX, etc.. Five focus areas were defined and approved for Animation Hub: 1) Medico, 2) News, 3) Science, 4) User Interfaces and 5) Open Source. The basic assumption was that animation as a strong communicative medium may have value outside the traditional areas of use and thus the aim was to explore these areas for alternative uses of animation and to disseminate knowledge about animation. This could potentially extend the field of work for animators and enrich the communicative powers of these five alternative areas of application.

Animation Hub[79] officially launched in January 2009 and was prolonged to include 2014. Animation Hub was officed at the internationally renowned school of animation *The Animation Workshop* (TAW)[80] in Viborg, Denmark. TAW has an experienced staff of lecturers and a steady flow of guest-lecturers from animationstudios around the globe. The graduates are mainly european and move on to national and international careers. Upon graduation the students earn a bachelor's degree in either Character Animation, Computer Graphics Art or Graphic Storytelling. Some students use the incubator environment connected to the school to establish their own studios. One of these studios – *Tumblehead*[81] created the animations for the research study used to collect empirical data for this project.

The Animation Hub focus area *User Interfaces* was re-cast into a Ph.D. researchproject, and based on my connection to Aalborg Unversity as an external lecturer and my professional experience with interaction design for small screens, I was offered the opportunity to define and execute the project. Thus, the research project named *Animated User Interfaces* was launched January 1st 2010. The project was created as a cooperation between *Animation Hub, Department of Humanities at Aalborg University* and industry partners *Nokia* and *Bang & Olufsen*. Nokia[82] and Bang & Olufsen[83] were already partners of Animation Hub, but chose to support the

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78 For infomation on Ministry of Higher Education & Science innovation-networks: ufm.dk

79 en.animationhub.dk

80 www.animwork.dk/en/

81 www.tumblehead.dk

82 company.nokia.com/en

83 www.bang-olufsen.com/en

User Interfaces focus area with extra funding because of their interest in the use of motion in interaction design for touch screen devices.

Unfortunately, both Nokia and Bang & Olufsen went through radically transformative periods after project commencement. This affected their commitment and participation in the project. Nokia went absent from the project as of late 2011 when their Copenhagen R&D site was closed. This moved the project rooting to Oulu, Finland. Following this, then the decision to terminate the Nokia proprietary Symbian and MeeGo sw platforms and base all Nokia smartphone development on the Microsoft WinPhone OS removed Nokias remaining involvement in the project. Nokia's exit left Bang & Olufsen as sole provider of technical resources for project activities, like development of prototypes and test-environments. In late 2011/ early 2012 Bang & Olufsen chose to reduce their user interface department and the remaining staff was now fully engaged in product development activities and did not have the bandwidth to support the Animated User Interfaces project. This also meant that Bang & Olufsen lost traction, and possibly also incentive, for keeping actively involved with the project.

The research has taken place in the environment of *Department of Communication & Digital Media* at Aalborg University and more specifically within the framework of the research-group *Interactive Digital Media*. The Interactive Digital Media research group[84] (InDiMedia) is focused on two primary areas: 1) The design, development and ontology of digital, interactive communication and products, and 2) Digitally supported experiences. The research group has existed for more than 10 years and the proliferation of interactive digital technologies and solutions, during this periode, has broadened the original scope. The research group embraces research interests in a spectrum which currently span the mechanisms of social media, the use of mobile devices in experience designs, studies of physiological data in mixed method research, and projects like this, which aim at better understanding how to design interactions and user interfaces. All research however is conducted from and within a user-centric perspective. The InDiMedia group therefore, like many other experience and HCI oriented research groups, represent a direct link to the Scandinavian School of Systems Development. An approach which, in the late 80'ies and 90'ies also formed the ontological and epistemological basis for the education in Human Computer Science that I commenced in 1991.

Personal background and experience

This section describe my professional and personal experience for researching touch screen interaction and animation.

I graduated with a degree in Human Computer Science from Aalborg University in 1997 and spend 10+ years in the mobile industry as User Interface Designer and User Interface Product Manager. My first assignment was to re-design the structure, mapping, layout and graphic looks of a handset operated by a ITU12 keypad, a

[84] www.indimedia.aau.dk

rocker-key, two softkeys and a 104x58 pixel black & white display. The device was aimed at the youth market, but was shelved due to sw-constraints. See Figure 63.

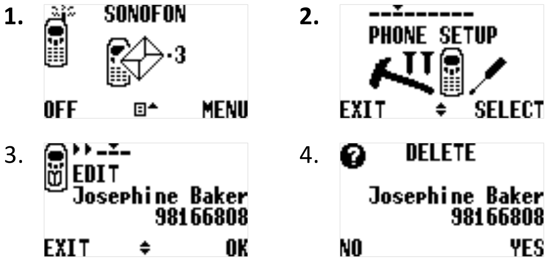

Figure 63. Examples from the Bosch a04 handset[85]: Image 1 is the idle state (stand by) with operator name, softkey texts, and a notification of three unread messages. Image 2 shows main-menu item 'Phone setup', softkey texts, rocker key indicators, and at the top the navigation-help that consisted of a location-pointer and a rectangular bar for each item at the current menulevel. Image 3 is from the Phonebook and shows the Edit option where the navigation-help now also indicates how many levels into the menu structure the user has moved. Image 4 shows a confirmation prompt from the Phonebook. Year: 1999.

As illustreted by Figure 63 then I tried to address the issue of loosing overview when navigating the hierarchical menus of a 2nd generation mobile phone by providing illustrations to support the text, and by offering graphic indicators of current position in the menusystem. The Nokia 3210 handset was released mid 1999 and adressed the same issues, but with more elegance and simplicity[86].

My career in the mobile industry started as handset design moved into 2nd generation and allowed me to design more than 30 different handset functionalities: Call handling, Phonebook, Messaging, Calendar, Calculator, Ringtone-composer and even the very first (and utterly over-hyped) internet for mobile: WAP[87]. The documentation part of my activities allowed me to develop an object-oriented approach to user interface documentation that enable independent control of each design-component. An approach which has had a large impact on my general undrstanding of design and design-thinking. My tenure in the mobile industry ended in 2008. Apple had disrupted the entire mobile market ecosystem in 2007 by introducing the one-button touch screen iPhone that allowed specific designs for each application, and the on-line app-store that enabled true personalisation of device functionalities; and opened up the mobile platform as a market for

[85] Previously un-published and rights probably owned by chinese Lenovo as Bosch Telecom was bought by german Siemens Mobile, which was acquired by korean BenQ, which sold the danish R&D department to us company Motorola. Google then acguired Motorola, but sold Motorola Mobility to Lenovo in late 2014.

[86] wired.co.uk/news/archive/2010-05/21/the-nokia-3210-was-the-greatest-phone-ever-made (accessed October 2016).

[87] en.wikipedia.org/wiki/Wireless_Application_Protocol (accessed October 2016).

independent sw developers. My employer Motorola, like the rest of the mobile industry, struggled at twisting their product roadmaps and multiple internally competing sw-platforms in shape for a competitive touch-solution. Radical decisions were required, and Motorola – sensibly – terminated all their development activities in Europe. Including the 450 R&D-positions in Aalborg where I worked. This allowed me to pursue the connection to Aalborg University that I had maintained since graduation.

This brings us to the autumn of 2009. At that time, I had limited knowledge and awareness of animation. I knew about the term and technique of 'stop-motion' and as a UI designer I had started investigating the use of 'transitions' between device states, but I had not paid professional attention to the extensive use of movement in e.g. the Apple iPhone. I had used and designed animations for the concepts I developed: Animated icons (Figure 64.) and animated indicators for device states like charging, searching, please wait, etc.

Figure 64. Animated Icon. Keyframes of an 11 frame animation that illustrated the menu item WAP. The icon would animate if focused and the frame indicates focus. All frames were stored as individual images. The animation represents my alternative version of the standard globe-representation of "internet-connectivty". Year: 2004

Animations like those in Figure 64 added an extra layer of explanation to the menu items, but were primarily meant as showcasing technical prowess because animation required software that executed well and our implementations should perform above state of the art.

For my design-work I used animated gifs to sketch and evaluate the perception and correlation between screen layouts when navigating menu-structures (but no smooth animated transitions between screens). But in general I did not think of movement as providing a special value of usability or pleasure. Animation was rather an illustrative aesthetic, adding to the dimensions of the device experience, not somthing to reduce cognitive load on a functional level.

Those are brifely my professional encounters with animation, but the pervasiveness of animation also means that I have many personal experiences. As a child I watched Disney's Bambi - I was 6, and I wept. I was entertained for hours by saturday afternoon cartoons and the seven minute Tom & Jerry short was the television-week highpoint.

Figure 65. Velociraptor from Jurassic Park. My drawing on iPad via image tracing.

Later, I watched Steven Spielberg's Jurassic Park on VHS and did not think: "Hey, there's an animated T-Rex". Probably, I had the chills and launched into a discussion about the realism in the cunning of the three Velociraptors. Which indicates that I did not question their existence as characters, but only the behaviour of the characters, as I would any other actors performance. Those three Velociraptors should rank high on the list of Hollywood-villains. Credit goes to the animators that made me believe in them[88]. In 2002 and 2003, I became father of two sons, so together we watched PIXARS *Cars* (2006) and we've watched all the *Ice Age* movies (2002, 2006, 2009, 2012) from Blue Sky Studios; from which the four main characters have become household references in our family. In general, then the types and contexts in which I have experienced animated products is quite extensive. It ranges from the afore mentioned classic cartoons and feature films to what one experiences when watching the news, concptual studies of new technologies or communication in museal settings. Animation is all around us. In most visual media and in most contexts. And motion is such a funamaental part of how to perceive and understand the world that we do not notice when animation, once again, is applied to illustrate something.

[88] Jurassica Park premiered in June 1993. It is a landmark production as this is the movie where an Instructor (Steven Spielberg) for the first time overturned the use of animatronics in favour of the image quality offered by CGI animation:
1. en.wikipedia.org/wiki/Jurassic_Park_(film)
2. www.youtube.com/watch?v=vxiKz8BJICU (accessed October 2016).

This is a fundamental view of the world. It says that when you build a thing you cannot merely build that thing in isolation, but must repair the world around it, and within it, so that the larger world at that one place becomes more coherent, and more whole; and the thing which you make takes its place in the web of nature, as you make it.

Christopher Alexander, 1977
A Pattern Language

A man-taught man would have picked his way with many stumbles through the cheating moonlight, but Mowgli's muscles, trained by years of experience, bore him up as though he were a feather. When a rotten log or a hidden stone turned under his foot he saved himself, never checking his pace, without effort and without thought.

Rudyard Kipling, 1895
The Spring Running in The Second Junglebook

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